

MAXIM

**1990
Seminar
Slide Book**

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APPLICATIONS TOPICS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG SWITCHES MULTIPLEXERS

- Input Protection

D/A CONVERTERS

- VDACS

AMPLIFIERS

- High Speed

VIDEO PRODUCTS

- Crosspoint Switch

REFERENCES

COMPARATORS

- High Speed

RS-232

- Isolation

μ P SUPERVISORY CIRCUITS

MAXIM

NEW LITERATURE

- 1990 Applications Handbook
- 1990 New Releases Data Book
- 1990 Short Form Catalog
- 1990 Military Products Data Book
- Maxim Engineering Journal (quarterly)
- Maxim Military Brochure
- Quality Assurance Manual
- Product Reliability Reports

MAXIM

MAXIM MILESTONES

Apr 1983 Founded
Jan 1988 New Facility:
 120 San Gabriel Drive
 Sunnyvale, CA.
Feb 1988 Public Stock Offering
 NASDAQ symbol: MXIM
Jul 1988 MIL Std 883 Qualification
Sep 1989 \$50 Million Annual Sales
Dec 1989 New Maxim Owned Fab

MAXIM

**MAXIM HAS INTRODUCED MORE
NEW PRODUCTS IN THE LAST 6
YEARS THAN ANY OTHER
ANALOG COMPANY**

MAXIM



MAXIM

Maxim's Commitment to Quality

- Extensive testing and quality control assures military quality for the commercial market at commercial prices
- All of Maxim's commercial products are fully traceable
- Maxim has received 893 certification
- RESULT: 8.7 FAILURES PER BILLION OPERATING HOURS

July 24, 1989

Electronic Engineering TIMES

Analog Angle

Two comers for the 1990s

"It's never easy to predict the future, but this time out I'm going to side with the industry analysts who are saying that two analog newcomers of the '80s stand a good chance of becoming major challengers to the big guys — Linear Technology and Maxim Integrated Products."

By Martin Gold

MAXIM

Maxim Quality With Rigorous QA Screening

ON EVERY MANUFACTURING LOT

- Test Yield Analysis
- Pressure Pot Testing
- Life Test
- E.S.D. Evaluation
- Latch-up Evaluation
- Noise Characterization

Maxim's Commitment to Quality

- Extensive testing and quality control assures military quality for the commercial market at commercial prices
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**RESULT: 5.7 FAILURES PER
BILLION OPERATING HOURS**

MAXIM

Maxim is dedicated to providing its customers with the best available product at a reasonable price. At Maxim, the "best" product is judged by its functionality, conformance to specifications, performance over time, delivery, and acceptance by the customer. These attributes can be generated by the terms "VALUE" and "QUALITY". Maxim's Quality Assurance Group oversees, and has explicit control of, all company operations.

Product quality is characterized at several different levels. We strive at Maxim to achieve the highest attainable level for our customers and ourselves. We believe that this is the only approach to developing mutually beneficial long term business relationships. This simple strategy has been instrumental in Maxim's growth as a leading supplier of quality products for the analog market.

Maxim Quality With Rigorous QA Screening

ON EVERY MANUFACTURING LOT

- Test Yield Analyses
- Pressure Pot Testing
- Life Test
- E.S.D. Evaluation
- Latch-up Evaluation
- Noise Characterization

MAXIM

In order to achieve the highest possible quality levels, Maxim reviews all reliability related parameters on a per lot basis. This provides measurably superior control of outgoing quality than is possible with quarterly or less frequent screen intervals used by many other manufacturers.

Package Unit Process Flow

Wafer Inspection

All wafers are fabricated using specifically developed processes with extremely tight control. Each must pass numerous in-process check-points for oxide thickness, critical dimensions, pin hole densities, and other requirements, and must comply with Maxim's demanding Electrical and Physical Specifications.

Finished wafers are inspected optically to detect any physical defects. Then they are parametrically tested to insure full conformity to Maxim's specifications. Our

parametric measurement capability has been specially designed by Maxim to make the precision measurements which are mandatory to insure reliability and reproducibility in analog circuits. We believe this quality control technology to be the best in the industry, capable of resolving below 1pA current levels, and less than 1pF capacitance. Maxim's proprietary software allows automatic measurement of subthreshold characteristics, fast surface state density, and other parameters which are crucial to predicting long term stability and reliability.

Every Maxim wafer is subject to this rigorous screening at no premium to our customers.

Testing

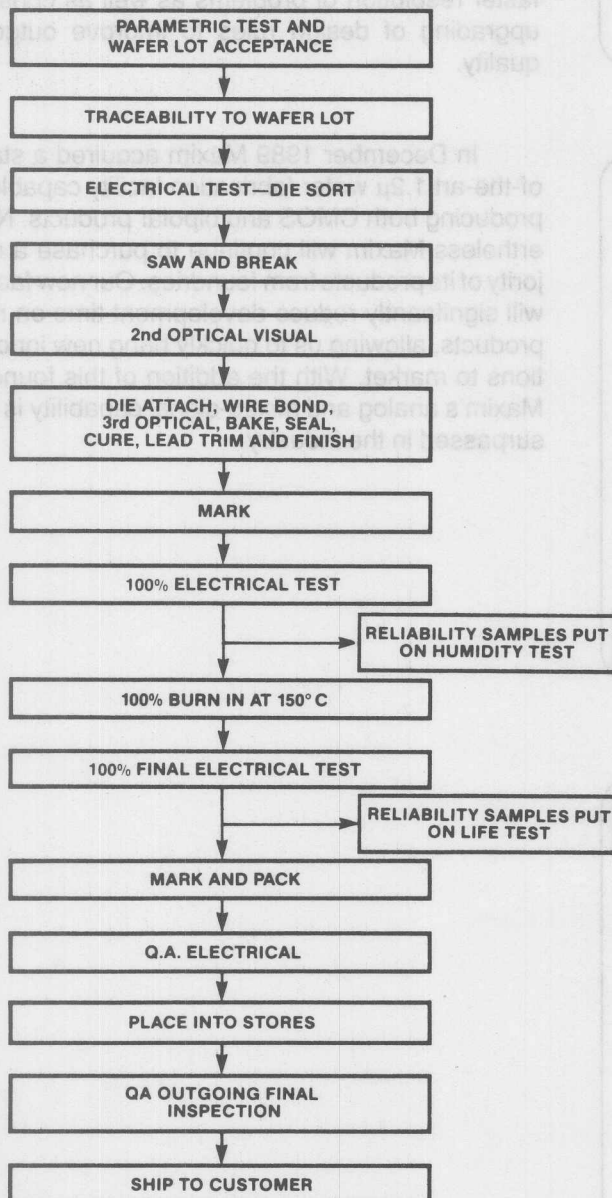
After wafer parametric inspection, each die is 100% tested prior to assembly. Once assembled, units are tested *over temperature*. This is not a common practice in the industry. By using the latest high speed automatic handling equipment, Maxim is able to offer "at temperature" testing for no additional cost.

Sophisticated testing is an integral part of delivering the highest quality data acquisition products. Maxim's analog test capability represents an order of magnitude improvement in accuracy, noise performance, and speed when compared to current industry standards. This provides the customer with total assurance that he will receive the part he paid for every time, without fail.

Product Conditioning and Qualification

Reliability of Maxim's products is further assured by subjecting parts to qualification cycles that include accelerated life tests equivalent to 20 million operating hours, as well as pressure and humidity ($85^{\circ}\text{C}/85\%$) cycles. In addition, *every unit shipped has been burned-in* (with the exception of reversed lead and Surface Mount Products—see below) to further reduce the possibility of field failure.

Products processed to this level are normally available from other manufacturers at a price premium, by ordering special process flows. *Maxim provides this testing and conditioning, including a 100% burn-in, at no additional cost.*



MAXIM

Designing In Reliability with Emission Microscopy

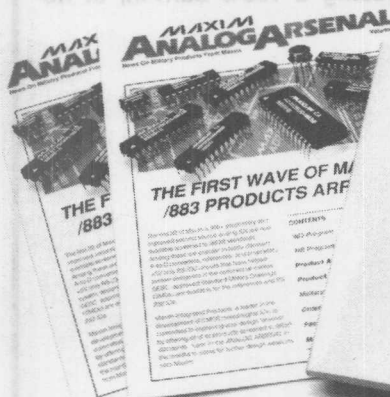
- "See" Current Flow
- Detects: Leakage
Latch-Up
Junction Breakdown
Defects
- Pinpoint and Correct Problems
- Improve Reliability

MAXIM

Maxim Buys Class 10 Wafer Fab

- Reduce process development time
- Improve time to market for new products
- Capable of 1.2 μ BiCMOS technology
- Foundries remain as major source of wafers
- Yield improvements reduce manufacturing costs and pricing
- Linear & mixed-signal process capability unsurpassed

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MAXIM
1990
Military Products
Data Book

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Tools and techniques for improving reliability are constantly reviewed and upgraded at Maxim. One of the newest is the "Emission Microscope". This device creates images from the invisible levels of light emitted by semiconductor devices. Current flow in the chip can actually be seen in nearly real time.

By using emission images, Maxim's engineers can optimize reliability and identify potential problem areas in designs. Device defects, leakage, latch-up events, voltage breakdown, and errant current flow can be pinpointed to specific locations on the die. The exact causes of such problems are then dealt with directly. The result is faster resolution of problems as well as constant upgrading of design rules to improve outgoing quality.

In December 1989 Maxim acquired a state-of-the-art 1.2 μ wafer fabrication facility capable of producing both CMOS and bipolar products. Nevertheless Maxim will continue to purchase a majority of its products from foundries. Our new facility will significantly reduce development time on new products, allowing us to quickly bring new innovations to market. With the addition of this foundry, Maxim's analog and mixed-signal capability is unsurpassed in the industry.

Military Product Availability

Parts currently /883 compliant:

MX581TH/883B	MX7524SQ/883B	MX7824TQ/883B
MX581SH/883B	MX7528UQ/883B	MX7828UQ/883B
MX584TH/883B	MX7528TQ/883B	MX7828TQ/883B
MX584SH/883B	MX7528SQ/883B	MAX232MJE/883B
MX584TQ/883B	MX7533UQ/883B	MAX232MLP/883B
MX584SQ/883B	MX7533TQ/883B	REF01AJ/883B
MX7225UQ/883B	MX7533SQ/883B	REF01AZ/883B
MX7225TQ/883B	MX7541UQ/883B	REF01J/883B
MX7226TQ/883B	MX7541TQ/883B	REF01Z/883B
MX7520UQ/883B	MX7541SQ/883B	REF02AJ/883B
MX7520TQ/883B	MX7541ASQ/883B	REF02AZ/883B
MX7520SQ/883B	MX7542GTQ/883B	REF02J/883B
MX7521UQ/883B	MX7542TQ/883B	REF02Z/883B
MX7521TQ/883B	MX7542SQ/883B	
MX7521SQ/883B	MX7572SQ05/883B	
MX7524UQ/883B	MX7572SQ12/883B	
MX7524TQ/883B	MX7824UQ/883B	

DESC approved devices to Standard Military Drawings currently available:

MILITARY PART #
5962-898770EA
5962-89877012C
5962-8958101GC
5962-8958101PA
5962-8958102GC
5962-8958102PA
8551401GC
8551401PA

Parts currently under /883 qualification:

MX580TH/SH	MAX694MJA
MX7224UQ/TQ	MAX695MJE
MX7543TQ/SQ	MAX696MJE
MX7545TA/SQ	MAX697MJE
MX7548SQ	MAX7645AM/BMJP
MX7574SQ	MAX8211MTV
MAX160MJN	MAX8212MTV
MAX690MJA	OP07AJ
MAX691MJE/MLP	OP07AZ
MAX692MJA	OP07J
MAX693MJE/MLP	OP07Z



APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLIERS

- Input

AMPLIFIERS

- Speed

VIDEO

- Cross

CONVERTERS

- Speed

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

- Isolation

CIRCUITS

MAXIM

POWER SUPPLY & DC-DC CONVERTERS

LINEAR REGULATORS

POSITIVE LOW POWER

- ICL7663 (variable)
- MAX663 (+5V or variable)
- MAX666 (+5V or var. inc. low batt. output)
- MAX667 (low dropout, +5V or variable)

NEGATIVE LOW POWER

- ICL7664
- MAX664 (-5V or variable)

SWITCHING REGULATORS

STEP UP

- MAX4193 (variable)
- MAX630 (variable)
- MAX631 (+5V or variable)
- MAX632 (+12V or variable)
- MAX633 (+15V or variable)
- MAX654 (+5Vout, +1Vin)
- MAX655 (+5Vout, +2Vin)
- MAX656 (+5Vout, +1Vin, Ext. FET)
- MAX657 (+3Vout, +1Vin)
- MAX658 (+5Vout, +2Vin, Ext. FET)
- MAX659 (+3Vout, +2Vin)

INVERTING

- MAX4391 (variable)
- MAX634 (variable)
- MAX635 (-5V or variable)
- MAX636 (-12V or variable)
- MAX637 (-15V or variable)

STEP DOWN

- MAX638 (+5V or variable)

DUAL OUTPUT

- MAX743 ($\pm 15V$ or $\pm 12V$)

CHARGE PUMPS

-Vin and 2x Vin

- ICL7660
- ICL7662 (high voltage)
- Si7661 (high voltage)

2x Vin AND -2x Vin

- MAX680
- MAX681 (caps incl.)

EXT. FET TO APPROX. 5 WATTS STEP UP/STEP DOWN/INV.

- MAX641 (+5V or variable)
- MAX642 (+12V or variable)
- MAX643 (+15V or variable)

MAXIM DESIGN NEWS

DC-DC CONVERTERS DELIVER 3V OR 5V FROM A SINGLE CELL

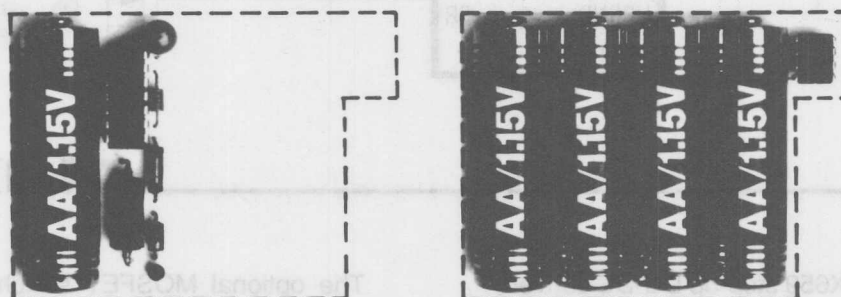
The MAX654-658 step-up DC-DC converters operate from low voltages such as those supplied by single-cell batteries. A typical conversion efficiency of 70% extends battery life, while a compact 14-pin design makes them ideal for portable instruments. The MAX654/5/6/8 provide a regulated 5V output, while the MAX657 provides a regulated 3V output.

The MAX654/5/7 with internal MOSFET are ideal for applications requiring less than 1W of output power, while the MAX656/8 and an external MOSFET should be used in applications requiring up to 2W of output power.

- ◆ 1.15V Start-Up (MAX654/6/7)
- ◆ 70% Efficient
- ◆ 80 μ A Supply Current in Standby Mode
- ◆ Auxiliary 12V/100 μ A Output
- ◆ Low Battery Indicator
- ◆ 14 Pin SO and DIP Packages

1V to 5V Converters Create Space

Team up a MAX654 converter with a few simple components and obtain a regulated +5V output while consuming less than half the board space of four AA batteries and a linear regulator.



Part	Battery Input (V)	Vout (V)	Iout(mA)	Price (1000-up)
MAX654	1 Cell: 1.15 - 1.55	5	45 - 80	\$3.34
MAX656*		5	190 - 380	\$3.34
MAX657		3	50 - 110	Available April
MAX655	2 Cells: 2.2 - 3.1	5	60 - 170	\$3.34
MAX658*		5	205 - 450	Available April

* Plus an IRF541 MOSFET

★ FREE DATA SHEETS ★

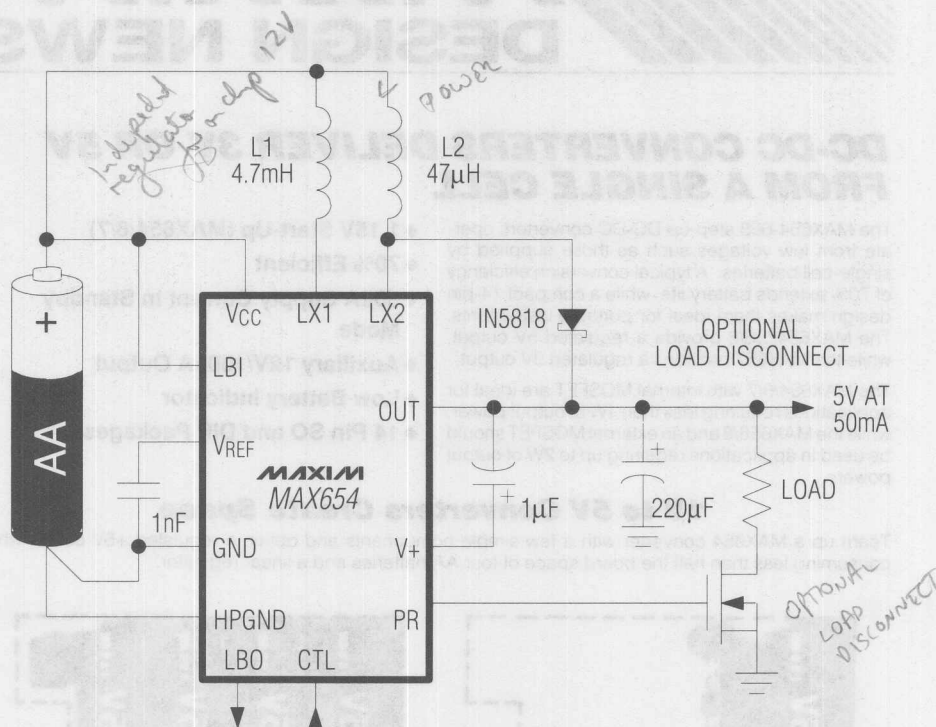
MAX654-8 (CIRCLE 10)
MAX480 (CIRCLE 11)
MAX641-3 (CIRCLE 12)

For **FREE SAMPLES** or applications assistance, call (408) 737-7600, FAX (408) 737-7194 or write Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086

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+5V at 50mA - MAX654

MAX655 Uses 2 Cells



MAXIM

The new MAX654-MAX659 step-up DC-DC converters efficiently generate a regulated +5V or +3V supply when the available input voltage is very low -- such as 1.3V from a single cell battery.

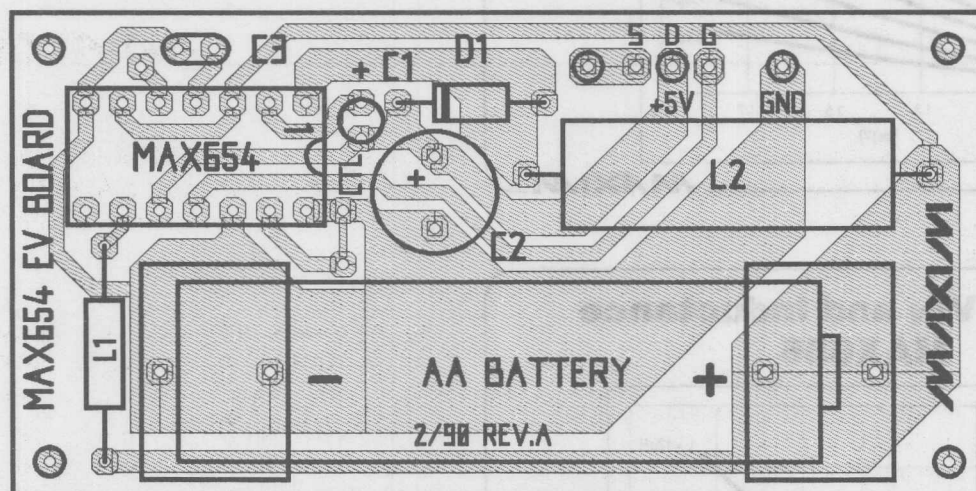
The converters are well-suited for battery-powered applications. A typical conversion efficiency of 75% extends battery life, while a compact 14-pin design makes them ideal for portable instruments. The MAX654/6/7 feature a guaranteed 1.15V start-up, and keep functioning as the input voltage drops under 1V.

The MAX654/5/7 with internal MOSFET are ideal for applications requiring less than 1W of output power, while the MAX656/8 and an external MOSFET should be used in applications requiring up to 2W of output power.

The optional MOSFET switch shown in the slide disconnects the load when the MAX654 is shut down. This prevents the battery from directly driving the load via the catch diode and coil.

PART	TYP INPUT RANGE (V)	OUT (V)	POWER SWITCH	OUTPUT (mA)
MAX654	1.15-1.56	5	Internal	40
MAX655	2.30-3.10	5	Internal	60
MAX656	1.15-1.56	5	Ext. FET	170
MAX657	1.15-1.56	3	Internal	60
MAX658	2.30-3.10	5	Ext FET	110
MAX659	2.30-3.10	3	Internal	60

MAX654 EV Board

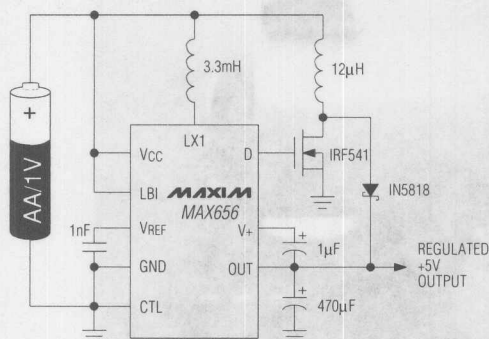


An evaluation kit is available for the MAX654 which demonstrates that a 5V output can be efficiently generated from one AA size NiCad or Alkaline battery. All components, including battery, fit in less space than is occupied by two AA cells. Battery life at a 10mA load is over 40 hours

MAXIM

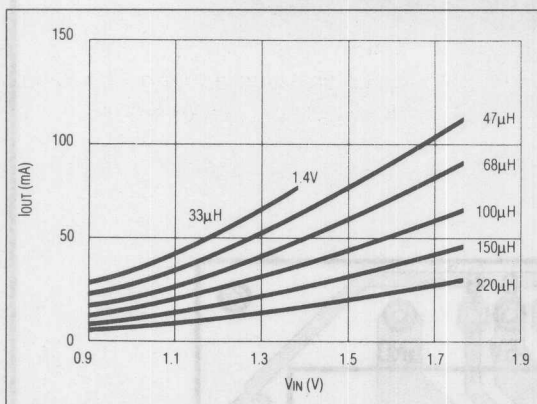
+5V at 250mA from Single Cell

- MAX656 uses one Ext. FET
- MAX658 uses 2 AA Cells



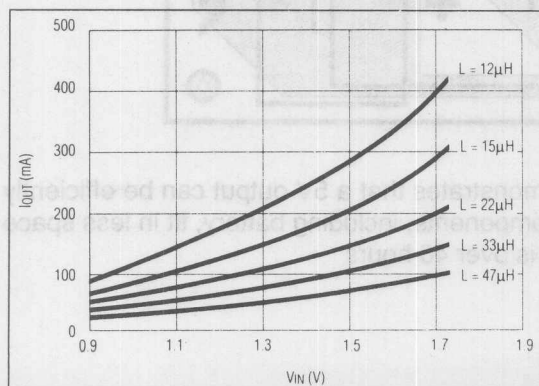
Higher output current than supplied by the MAX654 and 655 is possible with the MAX655 and 658. They directly drive a standard N-Channel MOSFET so component count is still low. The load disconnect N-FET used in the previous MAX654 circuit also works here.

I_{OUT} vs. V_{IN} and Inductance MAX654

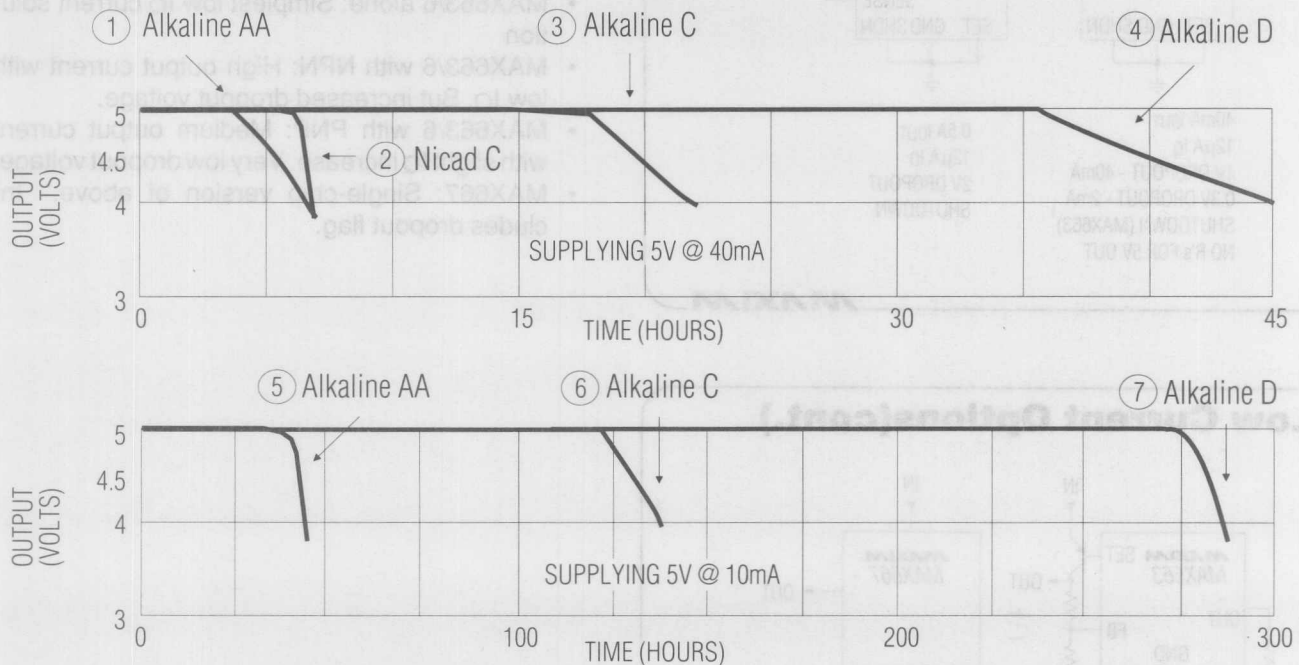


Available output current for the MAX654 and 658 are shown in these two slides. The graphs plot output current vs. input voltage for various inductance values. Output currents reflect the worst-case performance limits of IC. Select the IC and coil which supply the desired output current at the end-of-life battery voltage. The MAX654-659 data sheet contains similar graphs for the rest of the product family.

I_{OUT} vs. V_{IN} and Inductance MAX656



MAX654 Battery Life



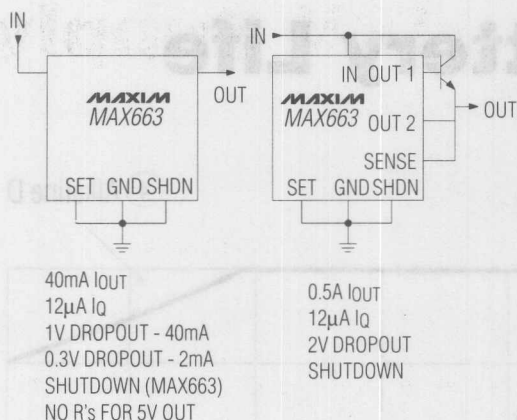
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Alkaline batteries, with relatively low output impedance (generally less than 1 ohm), and high capacity (7Ah for a typical C size cell) are good energy sources for the MAX654. The diagram shows typical battery life in

MAX654 circuits, providing 10mA and 40mA output at 5V. NiCad rechargeable batteries have much lower output impedance (typically 20mΩ) but less overall capacity per charge (2.2Ah for a C size cell).

TRACE	BATTERY	OUTPUT	BATTERY LIFE (HOURS)	END OF LIFE BATT. VOLTAGE	POWER INDUCTOR	ENERGY DELIVERED
1	Alkaline AA	5V @ 40mA	5	1.04V	63μH	1.0W-Hrs.
2	NiCad C	5V @ 40mA	7	1.1V	47μH	1.4W-Hrs.
3	Alkaline C	5V @ 40mA	20	1.01V	39μH	4.0W-Hrs.
4	Alkaline D	5V @ 40mA	40	1.0V	39μH	8.0W-Hrs.
5	Alkaline AA	5V @ 10mA	43	0.77V	114μH	2.15W-Hrs.
6	Alkaline C	5V @ 10mA	134	0.805V	150μH	6.7W-Hrs.
7	Alkaline D	5V @ 10mA	274	0.932V	157μH	13.7W-Hrs.

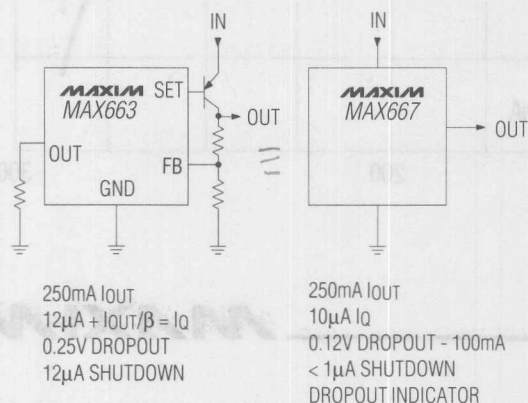
Low Current Regulator Options



A linear regulator may still provide power most efficiently in a battery operated system. With low input-output differentials, 70% or greater efficiency is not uncommon since quiescent current (I_Q) is low for all circuits. The regulators on these two slides offer advantages for different applications:

- MAX663/6 alone: Simplest low I_Q current solution
- MAX663/6 with NPN: High output current with low I_Q, But increased dropout voltage.
- MAX663/6 with PNP: Medium output current with slight I_Q increase. Very low dropout voltage.
- MAX667: Single-chip version of above. Includes dropout flag.

Low Current Options(cont.)

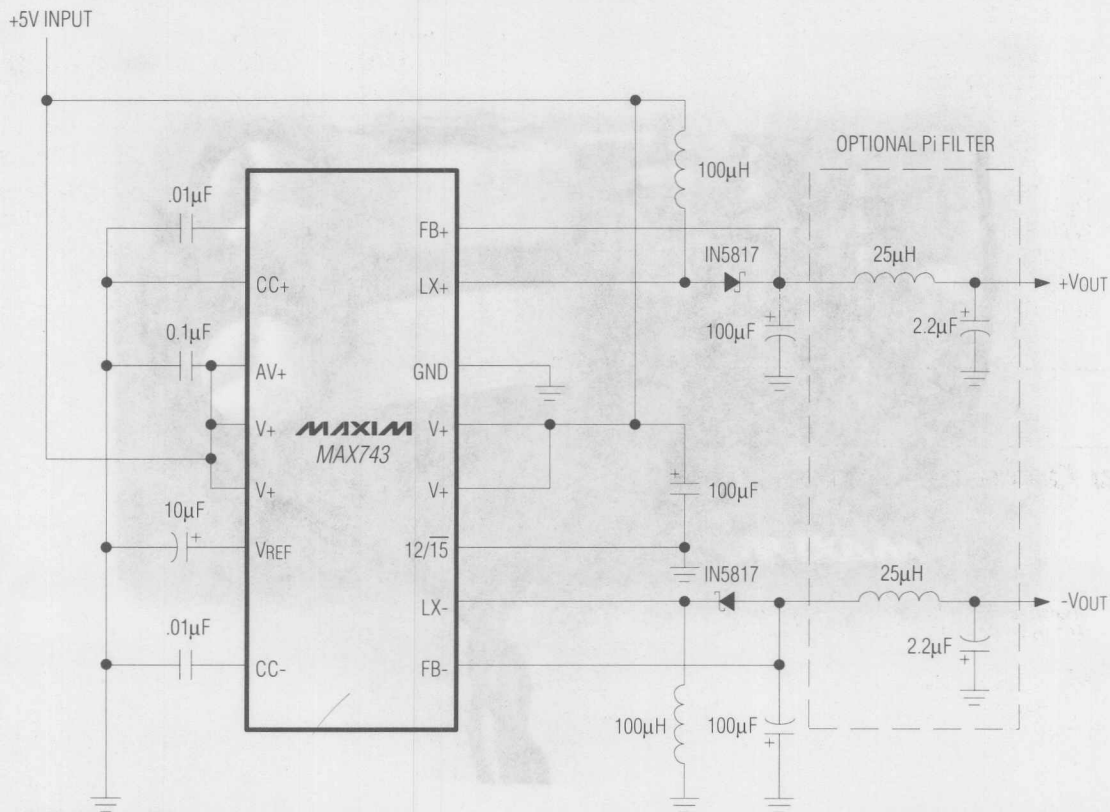


New +5V to ±15V MAX743

- ±100mA - Guaranteed In-Circuit
- Replace Modules at 1/3 Cost
- 80% Efficiency
- Current Mode - Low Noise
- EV Kit Available
- Production Kit Available

The MAX743's sophisticated features are typically found only on high power PWM controller ICs: Under-voltage lockout, thermal overload protection, cycle-by-cycle current limiting, and soft start are built in and require no additional components. Current-mode control provides excellent transient response and clean, low noise operation.

MAX743 - +5V to $\pm 15V$ Supply



MAXIM

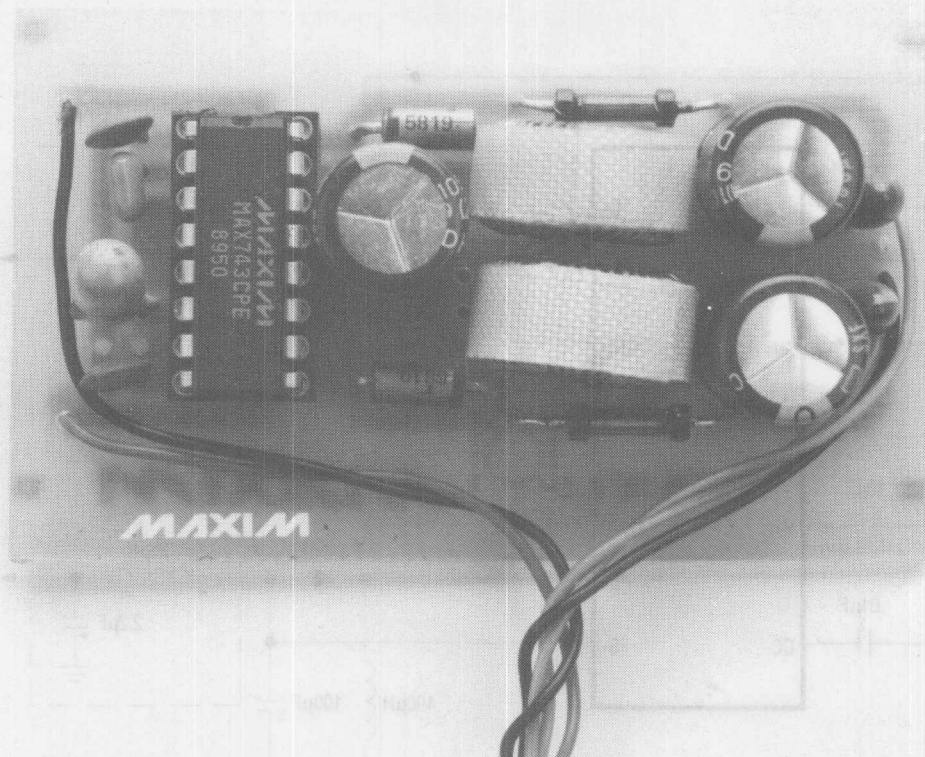
The MAX743 uses a minimum number of components to generate a regulated $\pm 12V$ or $\pm 15V$ output from a +5V source. A complete current-mode DC-DC converter can be built for less than one third the cost of pre-packaged DC-DC modules. Output noise and efficiency (80% typ) are also superior to most modules. The output current in THE FINAL APPLICATION CIRCUIT is guaranteed to be within 5% of $\pm 15V$ at $\pm 100mA$ output.

The MAX743 also supplies $\pm 12V$ at 120mA with the same circuit by toggling the 12/15 pin. No component changes are required to make this change. Also shown are optional LC output filters which further reduce output noise to below 5mV.

*80% efficient
but high (relatively)
quiescent current.*

*EV KIT available
(PPO)*

MAX743 - Dual DC-DC Converter



MAXIM

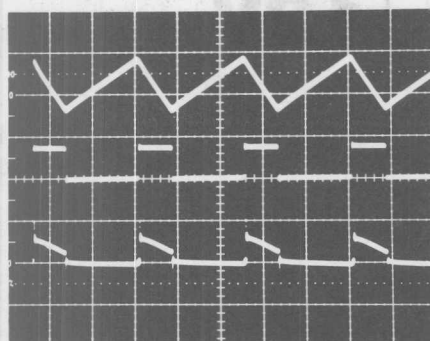
Clean, low-noise switching regulator operation requires a properly designed PC layout. This 2.5" by 1.25" board accommodates radial mount filter capacitors and inductors and includes space for an optional output Pi filter. An evaluation kit, with this PC board and all external components, is also available (order MAX743EV-KIT).

Production quantities of external components used with the MAX743 are available directly from Maxim. This simplifies component specification difficulties often encountered with inductors and other switching regulator

components. A complete DC-DC design becomes nearly as simple as a modular DC-DC converter, at less than 1/3 the cost.

The components kitted with MAX743 are low-noise toroid coils and low-ESR (Equivalent Series Resistance) aluminum electrolytic capacitors chosen for good performance over temperature and load extremes. The values of these components are relatively common and also work well with other Maxim switching regulators including the MAX630, MAX641, and MAX644/654 series.

MAX743 - Switching Waveforms



A = Inductor Current
50mA/DIV

B = Switch Voltage
20V/DIV

C = Output Ripple
50mV/DIV

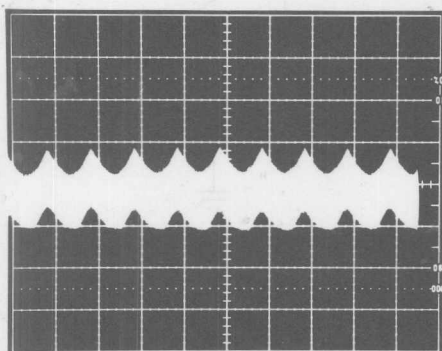
Horiz. = 2 μ s/DIV

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The step-up and inverting topologies employed in the MAX743 minimize parts count. The photo shows positive (step-up) section switching waveforms. When the switch turns on (trace B low), the coil connects to ground and coil current ramps up to a limit set by the feedback error signal. The switch then turns off, and the inductor discharges into the output filter capacitor. The majority of the ripple (trace C) is generated not by the filter cap discharging into the load, but by the internal IR drop of the capacitor as the inductor dumps its stored energy.

*determined by ESR OF CAP
helped by π filter (2mV noise).*

MAX743 - Noise With Pi Filter

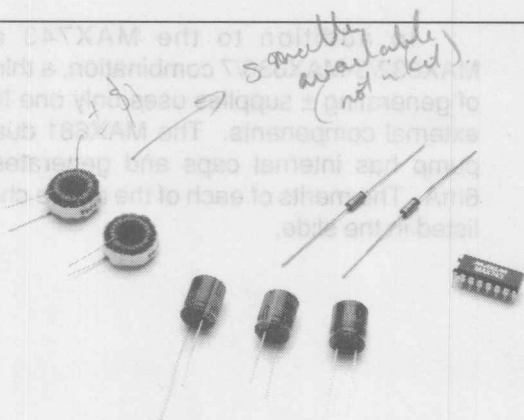


1mV/DIV

2 μ s/DIV

MAXIM

The lack of sub-harmonic low-frequency noise in the MAX743 output makes the optional Pi filter very effective in reducing noise. Very low filter choke inductance values can be utilized, which also keeps ringing and IR losses to a minimum. Ripple and noise are reduced to about 2mV P-P with this simple LC filter.

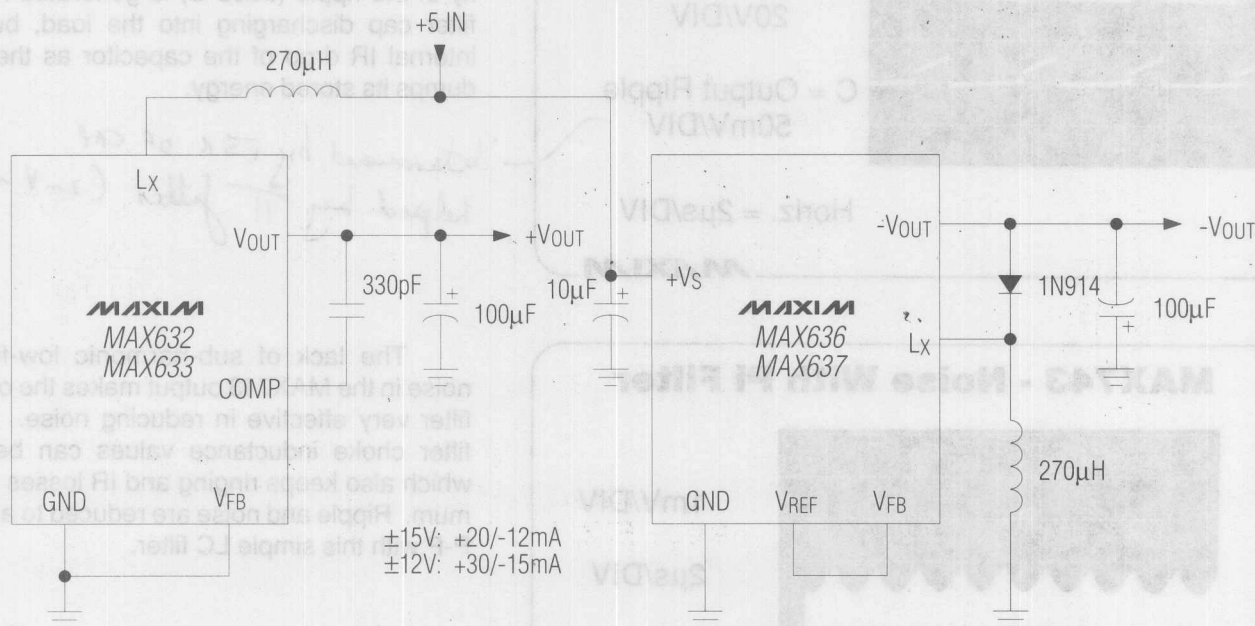


All major components required for a complete +5V to $\pm$ 15V or $\pm$ 12V DC-DC converter can be purchased directly from Maxim in kit form. Included components are:

- 1 - MAX743 IC
- 2 - 100 μ H Toroid Inductors
- 2 - Schottky Rectifiers
- 3 - Low-ESR Filter Capacitors

PRODUCTION KIT

Low Current ± 15 or $\pm 12V$



An alternate, lower output current, $+5V$ to $\pm 12V$ or $\pm 15V$ converter employs a MAX633 and MAX637 ($\pm 15V$) or a MAX632 and MAX636 ($\pm 12V$). Output current is

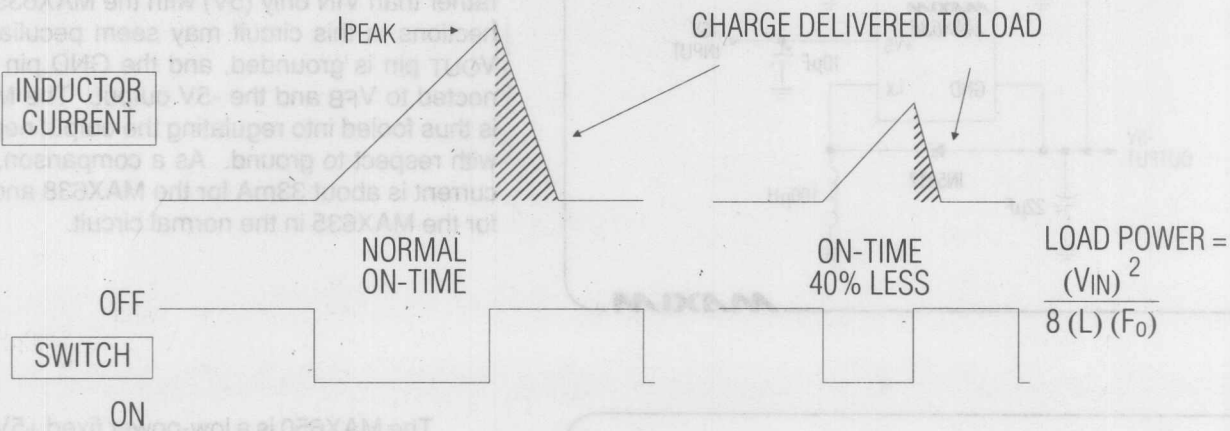
significantly less than with the MAX743 and ripple is greater, but quiescent current is less.

Comparison of $\pm$ Output Applications

Parameter	MAX743	MAX633/637	MAX680-681
Component Count	12	8	5/1 (no coils)
Load Capability	3 Watts	300mW	100mW
Efficiency	80%	75%	65%
Subharmonic Noise	low	medium	none
Oscillator	200kHz	50kHz	8kHz
Quiescent Current	8.0mA	200 μA	2mA
Output Voltage	$\pm 15/\pm 12$	$\pm 15/\pm 12$	± 10
Regulated	Yes	Yes	No

In addition to the MAX743 and the MAX632/3-MAX636/7 combination, a third means of generating $\pm$ supplies uses only one IC and no external components. The MAX681 dual charge pump has internal caps and generates $\pm 8V$ at 6mA. The merits of each of the above choices are listed in the slide.

New MAX63X Specs Mean 30 to 50% More Power



PART

OSCILLATOR FREQUENCY TOLERANCE

MAX635/6/7
MAX638
MAX631/2/3
MAX641/2/3

±12%
±11.2%
±10%
±10%

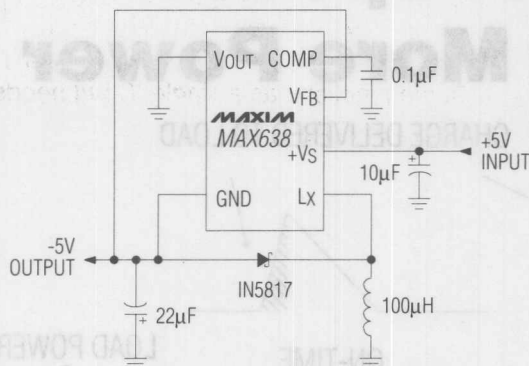
MAXIM

Tightened oscillator tolerance helps Maxim's MAX631, 635, 638, and 641 families of DC-DC converters deliver 30% to 50% more power than before. The diagram shows what happens if an oscillator frequency varies significantly from the expected design. When all else is equal, shorter on time keeps the inductor current from rising to a high enough value to supply the load demand. The result can be poor load regulation or insufficient output. A lower

than expected frequency can result in increased ripple and excessive switch and inductor current.

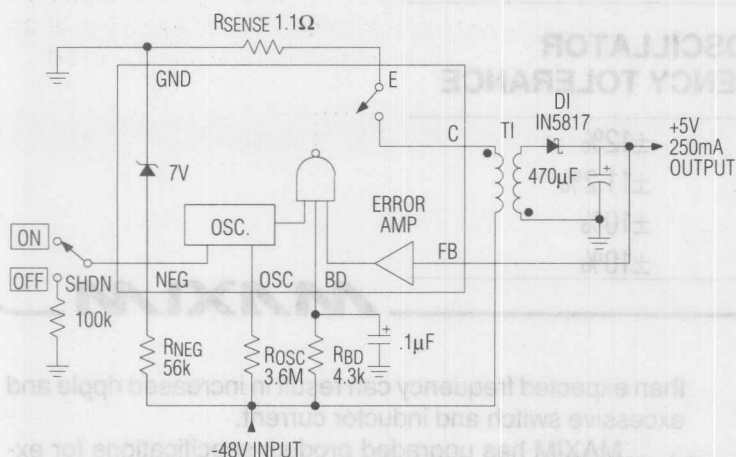
MAXIM has upgraded product specifications for existing devices by tightening limits and 100% testing oscillator frequency. All new switch-mode products also have guaranteed specs. Some devices, such as the MAX743, are laser-trimmed for maximum clock accuracy.

MAX638 +5V to -5V Supply



Normally, a step-down regulator, the MAX638 can also invert while providing more output at higher efficiency than the dedicated inverter (MAX635) in many applications. This is because a higher voltage is applied to the gate of the internal MOSFET switch; the gate sees the difference between V_{IN} and $-V_{OUT}$ (10V) with the MAX638, rather than V_{IN} only (5V) with the MAX635. Connections in this circuit may seem peculiar: The V_{OUT} pin is grounded, and the GND pin is connected to V_{FB} and the -5V output. The MAX638 is thus fooled into regulating the output negatively with respect to ground. As a comparison, output current is about 33mA for the MAX638 and 26mA for the MAX635 in the normal circuit.

MAX650 -48V to +5V at 250mA

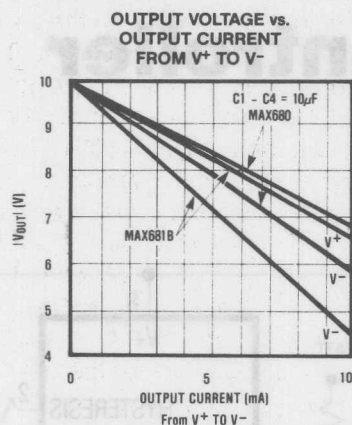


The MAX650 is a low-power fixed +5V output switching regulator that operates from high negative supplies. No external power switches are needed to operate from large negative input voltages such as those found in telecommunications systems. A typical operating circuit is shown at the left, in this case operating from a -48 volt telephone battery. With slight changes in component values, this circuit can operate with supply voltages as low as -10V. Transformers and other external components have been specified for both 100mA and 250mA output versions of the typical operating circuit.

MAX650 -48V to +5V Converter

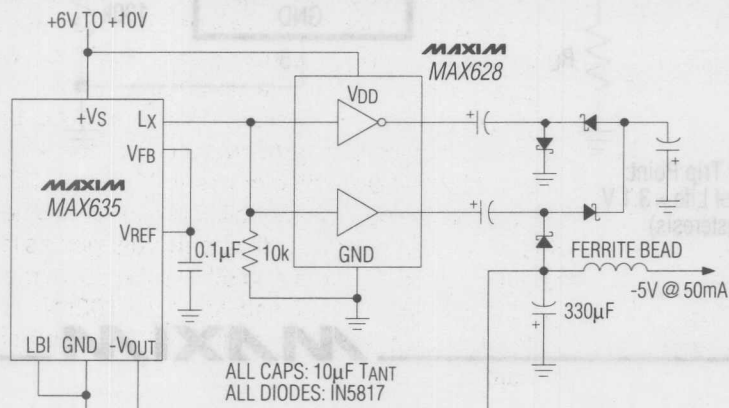
- Internal 140V, 250mA switching PNP
- Low component count
- Shutdown and soft-start inputs
- Low input voltage detector built-in
- 250mA @+5V output
- Short-circuit proof output

Charge Pumps for Low Power



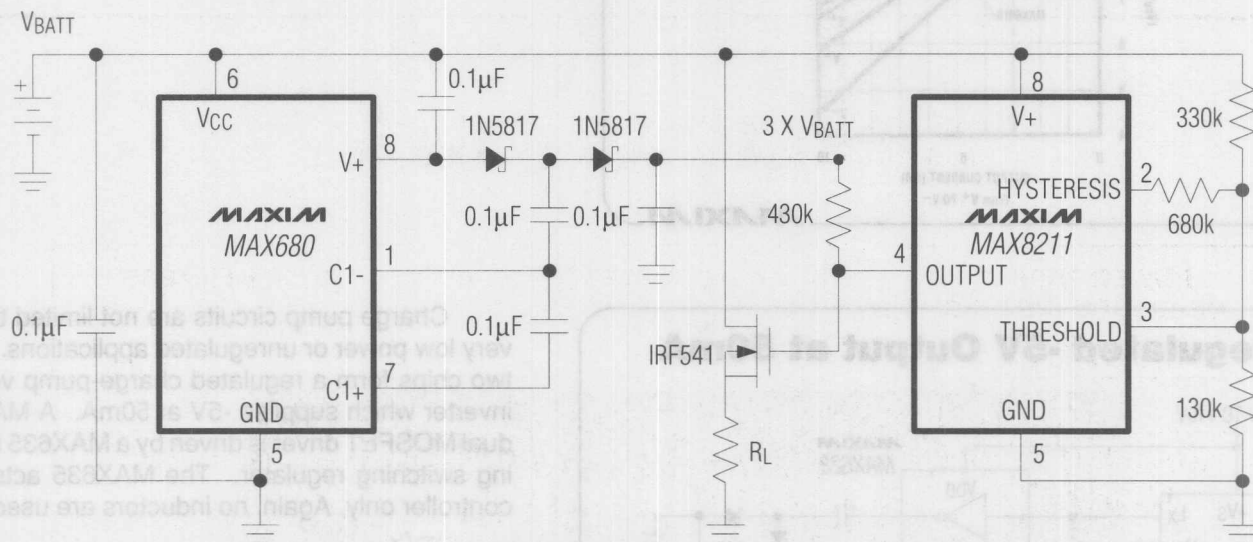
In many low power applications, power supplies can be generated without inductors by means of charge pump ICs or circuits. This graph shows output voltage versus current for the MAX680 and MAX681. The MAX680 uses four capacitors to turn a +5V input into $\pm 10V$ (unloaded). At 5mA the outputs are +8.5V/-8V. The MAX681 does the same functions as a single IC but needs no external capacitors.

Regulated -5V Output at 50mA



Charge pump circuits are not limited to only very low power or unregulated applications. Here two chips form a regulated charge-pump voltage inverter which supplies -5V at 50mA. A MAX628 dual MOSFET driver is driven by a MAX635 inverting switching regulator. The MAX635 acts as a controller only. Again, no inductors are used.

Battery Load Controller



Controller Trip Point:
Battery End of Life = 3.1 V
(1V Hysteresis)

MAXIM

A MAX680 charge-pump and a MAX8211 voltage detector form a battery protection circuit which prevents destructive battery discharge near end-of-life. The MAX680 triples the input voltage, providing the necessary voltage to drive the MOSFET gate. As long as the battery voltage is above the level set at the MAX8211, the

MOSFET remains on. When the battery voltage falls, the MOSFET turns off, removing the load from the battery. The MAX680 acts as a "high-side" driver, so that a low cost, low resistance N-Channel MOSFET may be used as an efficient switch.

APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLIERS

- Input

ACTIVE FILTERS

- Lower Noise

VIDEO

- Cross

- Isolation

CIRCUITS

MAXIM

ACTIVE FILTERS

SWITCHED CAPACITOR FILTERS

CONTINUOUS FILTERS

UNIVERSAL

μP PROG.

- MAX260 (7.5kHz)
- MAX261 (57kHz)
- MAX262 (140kHz)

PIN PROG.

- MAX263 (57kHz)
- MAX264 (140kHz)

RESISTOR PROG

- MAX265 (57kHz)
- MAX266 (140kHz)

BANDPASS PIN PROG.

- MAX 267 (57kHz)
- MAX268 (140kHz)

ZERO ERROR LOWPASS

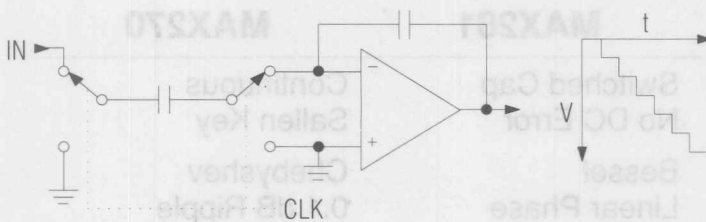
- MAX280 (20kHz)
- LTC1062 (20kHz)
- MAX281 (20kHz)

LOWPASS, 2nd ORDER

- MAX270 (1-25kHz)
- MAX271 (1-25kHz)

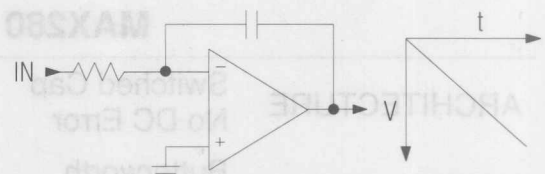
Switched-Cap vs. Continuous Active Filters

Switched Cap



- High accuracy
- Clock tunable
- Realize complex filters

Continuous



- No clock noise
- Not sampled-no aliasing
- Needs no clock
- Low noise & offset

MAXIM

Maxim utilizes two different design approaches in active filter products - Switched Capacitor filters and Continuous (not sampled) filters.

In switched-cap filters, switched capacitor integrators "simulate" continuous op amp integrators but in fact contain clocked (switched) input capacitors. The integrator time constant is proportional to the clock frequency so the filter can be tuned by varying the clock or, with the MAX260 series, by digital programming. Another major advantage is high accuracy without external components.

Switched capacitor filter output signals do include some clock feedthrough and noise, although this is easily filtered externally since the clock noise is at frequencies

much higher than (typ. 100 times) the cutoff frequency. Also, input signals must be band-limited to below one half the filter clock rate, since the filters are in fact "sampling" systems and aliasing is possible with wide-band inputs.

Continuous filters are essentially standard op amp and capacitor circuits, and are not sampled. The MAX270 fully integrates two 2nd-order Sallen-Key lowpass filters. No clock or external components are required; programming is achieved by selecting on-chip capacitors. Noise is far lower than that of switched-cap filters, however filter accuracy and programmability are not quite at switched-cap levels.

Lowpass Filter Design Guide

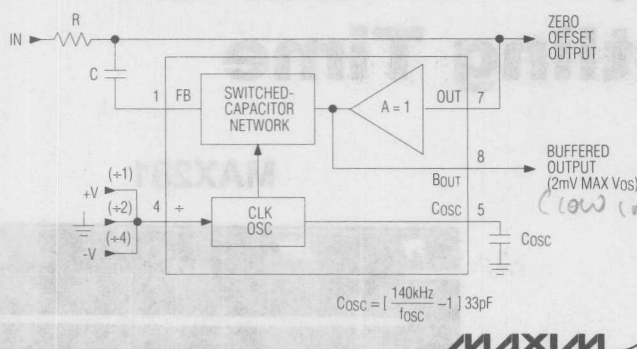
	MAX280	MAX281	MAX270
ARCHITECTURE	Switched Cap No DC Error	Switched Cap No DC Error	Continuous Sallen Key
RESPONSE	Butterworth Approximation	Bessel Linear Phase	Chebyshev 0.1 dB Ripple
ORDER	5th Order	5th Order	Dual 2nd Order
f_c RANGE	0-20kHz	0-20kHz	1kHz - 25kHz
DYNAMIC RANGE	85dB (RC clock filter)	85dB (RC clock filter)	96dB
PROGRAMMING	Clock and External RC	Clock and External RC	Pin Strap or Microprocessor
ON-CHIP FEATURES	Buffered Output, Internal Clock	Buffered Output, Internal Clock	Extra Op Amp No Clock Noise

MAXIM

Three choices for single-chip lowpass filters are the MAX280, MAX281 and MAX270. The MAX280 and 281 are 5th order switched-cap filters. Their architecture is such that the chip handles only the AC component of the input signal, while DC is passed with perfect accuracy. The MAX280 is a butterworth lowpass while the MAX281 employs a Bessel function.

The MAX270 dual 2nd-order continuous lowpass filter is a monolithic version of the common Sallen-Key lowpass often built with discrete op amps. Microprocessor or pin-programmable, the MAX270 is instantly set from 1kHz to 25kHz. Its continuous design requires no clock and so eliminates clock noise and aliasing limitations of its switched-cap counterparts.

MAX280 - BUTTERWORTH
MAX281 - BESSEL



OUTPUT
(2mV MAX V_{OS})
(low impedance)

Figure 1 is a line graph showing the phase lag (in degrees) versus frequency (in Hz) for two devices, MAX280 and MAX281. The y-axis represents Phase Lag (degrees) from 0 to -400. The x-axis represents Frequency (Hz) from 0 to 2K. A reference line for $f_c = 1.0\text{kHz}$ is shown. MAX280 has a phase lag of approximately -250 degrees at 1KHz, while MAX281 has a phase lag of approximately -350 degrees at 1KHz.

Frequency (Hz)	MAX280 Phase Lag (degrees)	MAX281 Phase Lag (degrees)
0	0	0
1K	-250	-350
2K	-300	-380

The MAX281, 5th-order Bessel lowpass, phase response is nearly linear throughout the passband and into the stopband. Linear phase also corresponds to constant group delay (group delay is the negative derivative of the phase response). All spectral components therefore are passed with approximately equivalent delay, which is useful in real-time applications, and where fast-settling time-domain response is important.

INPUT
5V/DIV

BUTTERWORTH
max280 OUTPUT
2V/DIV

BESSEL
MAX281 OUTPUT
2V/DIV

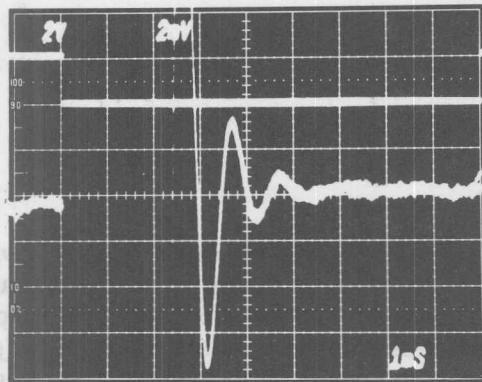
1msec/div

The step response of the MAX280 clearly exhibits ringing and overshoot, while the MAX281 Bessel gives a smoothed ("low-passed") but otherwise undistorted version of the input step.

The nonlinear phase response of the MAX280 shifts components of the input signal in time by various amounts, depending on their frequencies. The overall effect is to distort non-sinusoidal waveforms (such as the step input shown). The MAX281 Bessel filter, with linear phase response, shifts all input signal components equally in time, regardless of frequency, thereby delaying but not distorting the waveform.

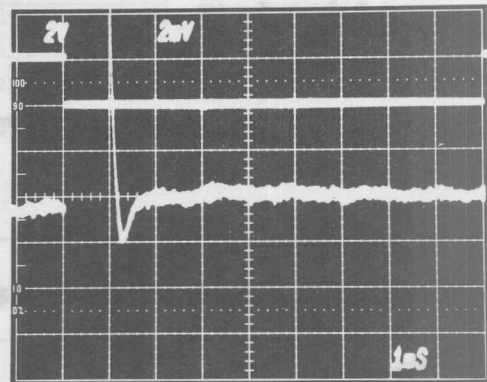
MAX280/MAX281 0.1% Settling Time

MAX280



5 msec

MAX281



1.5 msec

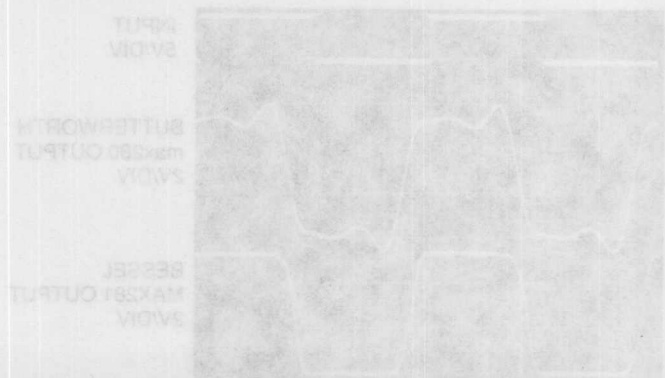
1kHz Lowpass filter

MAXIM

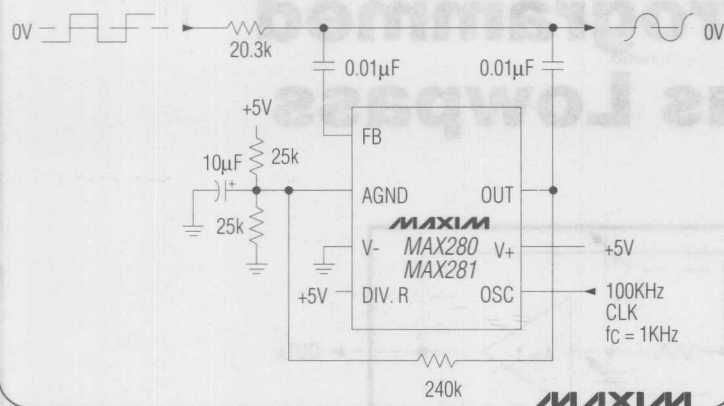
Shown here are settling characteristics of the MAX280 and MAX281 to 0.1% for a step input. The absence of ringing in the MAX281 response yields a settling time of less than one third that of the MAX280. This performance is important in data acquisition. For

example, in weight scales or voltmeters, a fast changing input signal often goes through an anti-aliasing or lowpass filter before digital conversion. Abrupt step changes at the input must settle to their final DC value quickly, especially in multi-channel systems.

MAX280/MAX281 Step Response

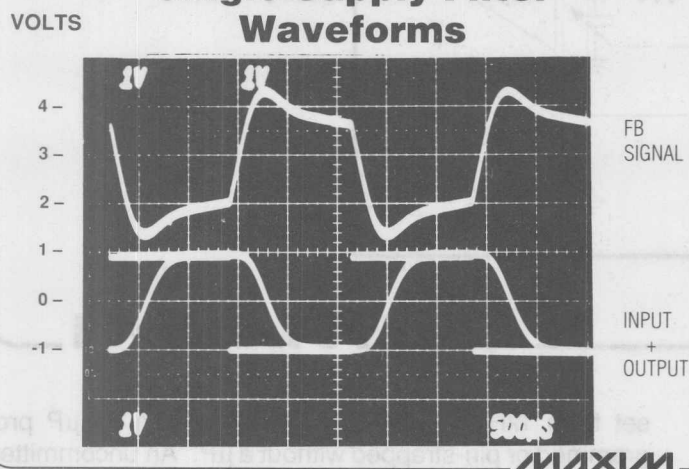


Single Supply Filter Handles Bipolar Signals



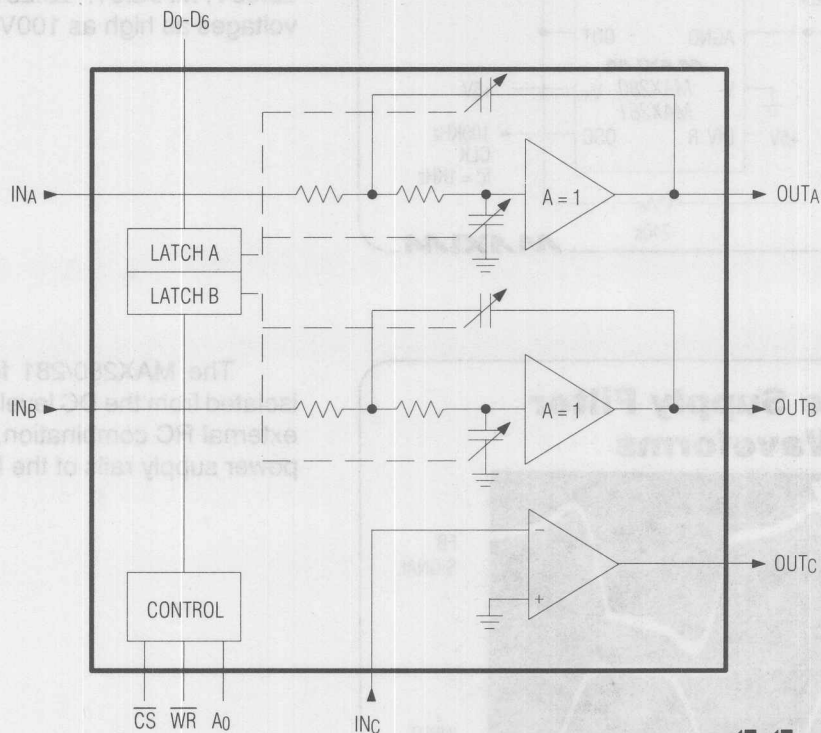
Since the architecture of the MAX280/281 blocks the DC signal from entering the chip, these filters have the unique ability to filter signals with DC voltage levels outside their power supply rails. The circuit shows a bipolar $\pm 1\text{V}$ input signal filtered by a MAX280/281 powered from a single 5V supply. As long as the peak-to-peak AC input signal is within the input range of the filter (MAX280: $\pm 2.35\text{V}$, MAX281: $\pm 3.25\text{V}$) signals with DC offset voltages as high as 100V can be filtered.

Single Supply Filter Waveforms



The MAX280/281 feedback pin, effectively isolated from the DC level of the input signal by the external RC combination, still operates within the power supply rails of the MAX280/281.

MAX270 Programmed Continuous Lowpass

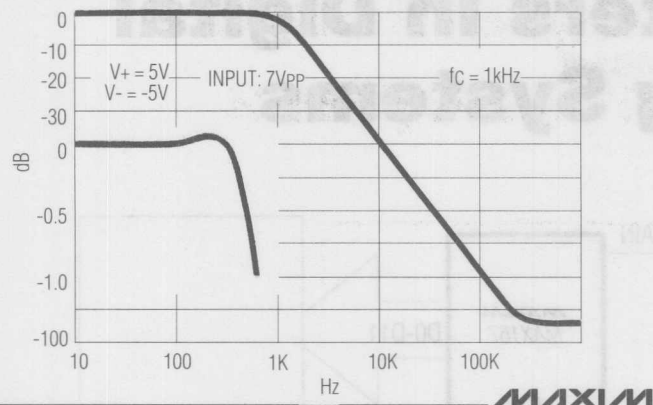


MAXIM

The MAX270 Dual Continuous Chebyshev filter contains two second-order Sallen-Key filter sections on a 20 pin chip. Separate data latches for each filter section hold programmed cutoff frequency values which can be

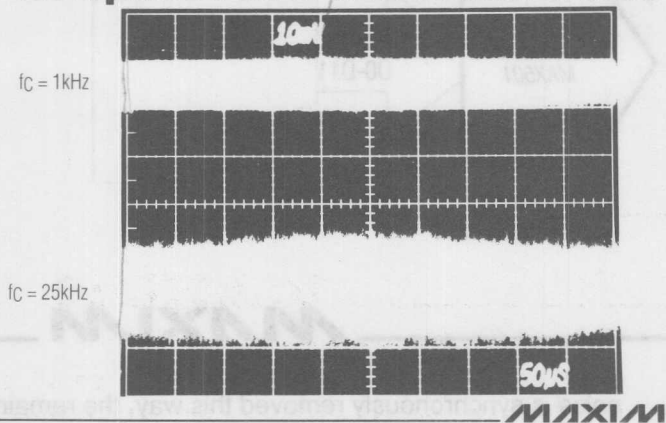
set from 1kHz to 25kHz. The filters can be μP programmed or pin-strapped without a μP . An uncommitted amplifier is provided on-chip as well.

MAX270 Continuous Filter Chebyshev Lowpass Response



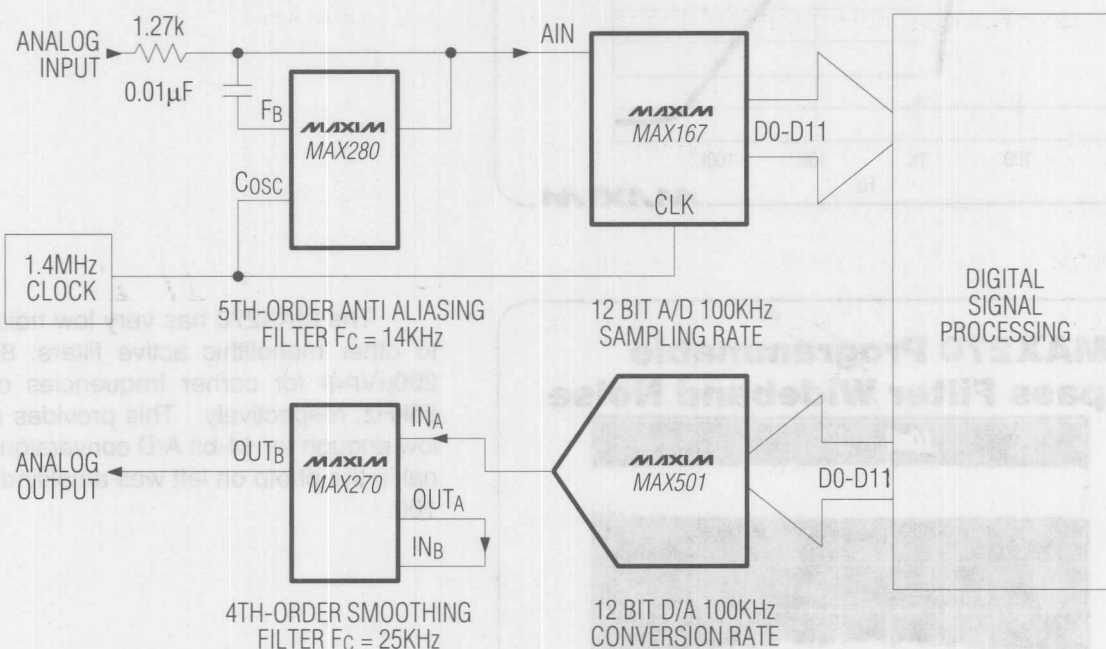
frequency response with typically 0.1dB of peaking in the passband. Dynamic range is typically greater than 106dB for a filter cutoff of 1kHz as shown. For $f_c = 25kHz$, dynamic range is about 96 dB. No extra output filtering is needed to achieve these results.

MAX270 Programmable Lowpass Filter Wideband Noise



The MAX270 has very low noise compared to other monolithic active filters: $80\mu V_{P-P}$ and $200\mu V_{P-P}$ for corner frequencies of 1kHz and 25kHz, respectively. This provides a noise floor low enough for 14-bit A/D conversions. Noise signal in the photo on left was amplified by a gain of 100.

Lowpass Filters In Digital Sampling Systems



MAXIM

Analog input and output filtering is easily added to a 12-bit signal processing system. A MAX280 zero-DC-error 5th-Order lowpass provides anti-aliasing filtering. The MAX167 12-bit A/D includes an internal track-and-hold and samples the input at a 100kHz rate. The MAX280 drives the analog input of the A/D directly, so no offset is introduced. Clock noise from input filter is "deintegrated" by synchronizing the MAX167 with the MAX280 clock to track the input signal for a whole number of clock cycles before holding for conversion. Once clock

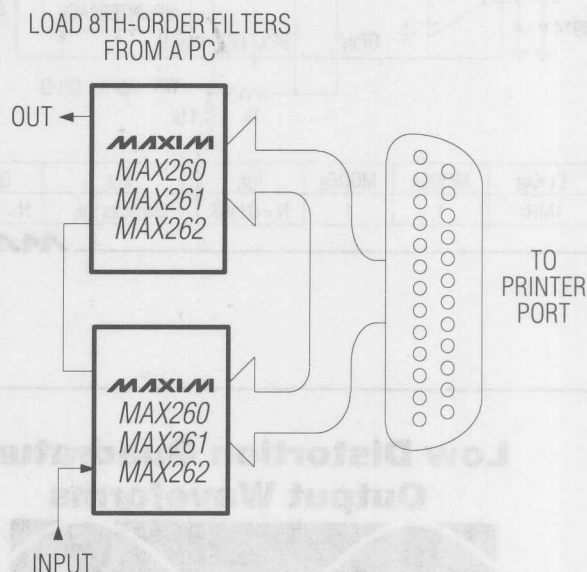
noise is synchronously removed this way, the remaining wideband filter noise is low enough for 12-bit A/D conversion.

The MAX501 12-bit DAC output is smoothed by two cascaded 2nd-order sections of a MAX270 continuous lowpass set at 25kHz. No clock noise is introduced into the output signal because this filter uses no clock.

MAX260 Filter Family

- Dual 2nd-Order Programmable Switched-Capacitor Filters
- Lowpass/Bandpass/Highpass/Allpass/Notch

Part No.	Fc Range	Programming
MAX260/1/2	0.01 Hz - 140 kHz	Microprocessor
MAX263/4	0.4 Hz - 140 kHz	Pin Strap
MAX265/6	0.4 Hz - 140 kHz	Resistor/Pin Strap
MAX267/8	0.4 Hz - 140 kHz	Resistor/Pin Strap

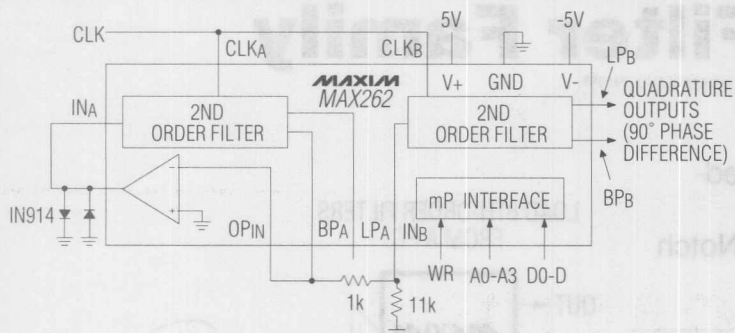


The MAX260 series are switched capacitor state variable filters configurable as Lowpass, Bandpass, Allpass, Notch, and Highpass filters. Each contains two fully programmable second-order sections. These are Maxim's most "general purpose" filters. Available ver-

sions can be programmed from a μ P, by pin-strapping, or with external resistors. A wide variety of filter functions such as Butterworth, Chebyshev, elliptic, etc. can be realized. Design time is shortened with the aid of Maxim's filter design software.

MAXIM

Low Distortion Programmable Quadrature Oscillator—MAX262



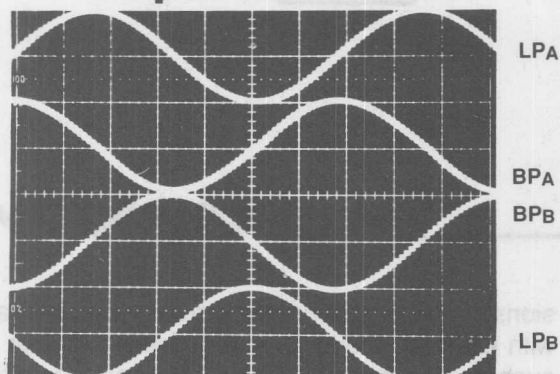
CLKAB	MODEA	MODEB	f _{OA}	f _{OB}	Q _A	Q _B
1MHz	1	1	N = 0 to 63	Same as f _{OA}	N = 120	N = 120

MAXIM

A MAX262 dual 2nd-order programmable universal filter implements a novel tunable low distortion quadrature "oscillator". Sine and Cosine waveforms are generated 90° apart. Such waveforms are useful in single side band modulators and coherent demodulators, and even to drive synchronous motors.

Each filter section in the MAX262 has both bandpass (BP) and lowpass (LP) outputs. The output of the first bandpass (BPA) is clipped by diode feedback clamps at the on-chip amplifier. The two quadrature outputs appear at LPB and BPB. The output frequency is the input clock divided by the digitally programmed f_{CLK}/f_o ratio. For a given clock frequency, the oscillation frequency can be set with approximately 2% accuracy over a 1-to-3.5 range. Further, by altering the clock frequency, the oscillator range varies from a few Hz to typically 75KHz.

Low Distortion Quadrature Output Waveforms



MAXIM

APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLIERS

- Input

VIDEO

- Cross

- Isolation

A/D CONVERTERS

AMPLIFIERS

speed

GENERATORS

speed

CIRCUITS

MAXIM

A/D CONVERTERS

FAST CONVERSION ($<100\mu\text{s}$) (SAR/FLASH A/Ds)

SLOW CONVERSION ($>100\text{ms}$) (SEE INTEGRATING A/Ds)

8-BITS

SINGLE CHANNEL

INTERNAL T/H

- MAX150 (1.34 μs /Ref)
- MX7820 (1.34 μs)
- ADC0820 (1.38 μs)
- MAX165 (5 μs /Ref)
- MAX166 (5 μs /Ref)

EXTERNAL T/H

- MAX160 (4 μs)
- MX7575 (5 μs)
- MX7576 (10 μs)
- MX7574 (15 μs)

MULTI-CHANNEL

INTERNAL T/H

- MAX154 (2 μs /4 Ch/Ref)
- MAX158 (2 μs /8 Ch/Ref)
- MX7824 (2 μs /4-Ch)
- MX7828 (2 μs /8 Ch)
- MAX155 (3 μs /Ref/8-Ch)
- MAX156 (3 μs /Ref/8-Ch)

EXTERNAL T/H

- MAX161 (20 μs /8 Ch)
- MX7581 (67 μs /8 Ch)

10-BITS

INTERNAL T/H

- MAX151 (1.9 μs /Ref)
- MAX177 (10 μs /Ref)

EXTERNAL T/H

- MAX173 (5 μs /Ref)

12-BITS

SINGLE CHANNEL

INTERNAL T/H

- MAX163 (10 μs /Ref)
- MAX164 (10 μs /Ref)
- MAX167 (10 μs /Ref)

EXTERNAL T/H

- | | |
|--|-------------------------------------|
| • MX578 (3 μs /Ref) | • MAX174 (8 μs /Ref) |
| • MAX162 (3.25 μs /Ref) | • MAX172 (10 μs /Ref) |
| • MAX169 (3.25 μs /Ref) | • MX7672-10 (10 μs) |
| • MX7672-03 (3.25 μs) | • MX7572-12 (12 μs /Ref) |
| • MAX170 (5 μs /Ref/Serial) | • MX674A (15 μs /Ref) |
| • MAX171 (6 μs /Ref/Serial) | • MX574A (25 μs /Ref) |
| • MX7572-05 (5 μs /Ref) | • MAX178 (50 μs /Ref) |
| • MX7672-05 (5 μs) | • MX7578 (100 μs) |

MULTI-CHANNEL

INTERNAL T/H

- MAX180 (8.33 μs /Ref/8-Ch)
- MAX1821 (8.33 μs /Ref/6-Ch)
- MAX182 (40 μs /Ref/4-Ch)

EXTERNAL T/H

- MX7582 (100 μs /4 Ch)

A/D CONVERTERS

FAST CONVERSION
($<100\mu\text{s}$)
(SEE SAR/FLASH A/Ds)

SLOW CONVERSION
($>100\text{ms}$)
(INTEGRATING A/Ds)

LCD DISPLAY

- ICL7106
- ICL7116 (HOLD)
- MAX136 (HOLD)
- ICL7126
- ICL7136
- MAX130 (B/G)
- MAX138 (C/P)
- ICL7129 (4 1/2 DIGIT)

LED DISPLAY

- ICL7107
- ICL7117 (HOLD)
- MAX139 (B/G, C/P)
- MAX140 (B/G, C/P)
- ICL7135 (4 1/2 DIGIT)
- MAX131 (B/G)

μP INTERFACE

- ICL7109 (12 BIT)
- ICL7135 (4 1/2 DIGIT)
- MAX133 (40,000 COUNT)
- MAX134 (40,000 COUNT)

NOTE

C/P	Generates -5V internally
HOLD	Has hold display input
B/G	Has bandgap reference for improved stability

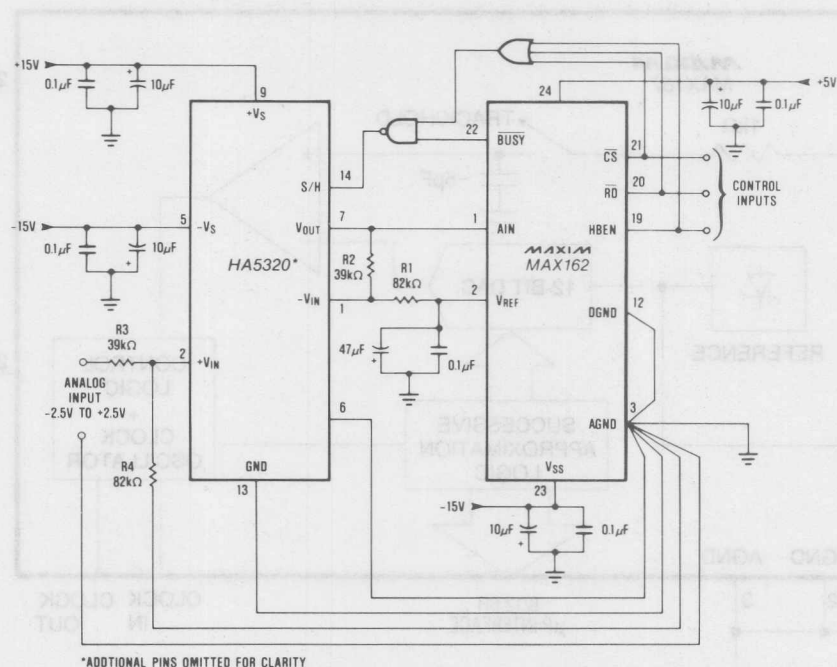
MAXIM'S SECOND SOURCES OF ANALOG DEVICES

Analog Devices	Maxim	Analog Devices	Maxim
AD2700	MX2700	AD7535	MX7535
AD2701	MX2701	AD7536	MX7536
AD2710	MX2710	AD7537	MX7537
AD3554	MX3554	AD7541A	MX7541A
AD517	MAX400	AD7541	MX7541
AD536	MX536	AD7542	MX7542
AD565	MX565	AD7543	MX7543
AD566	MX566	AD7545	MX7545
AD578	MX578	AD7548	MX7548
AD580	MX580	AD7572	MX7572
AD581	MX581	AD7574	MX7574
AD584	MX584	AD7575	MX7575
AD586	MAX675	AD7576	MX7576
AD589	ICL8069	AD7581	MX7581
AD7224	MX7224	AD7628	MX7628
AD7225	MX7225	AD7820	MX7820
AD7226	MX7226	AD7824	MX7824
AD7228	MX7228	AD7828	MX7828
AD7520	MX7520	ADG201	DG201
AD7521	MX7521	ADG202	DG202
AD7523	MX7523	ADG508	DG508
AD7524	MX7524	ADG509	DG509
AD7528	MX7528	ADLH0033	LH0033
AD7530	AD7530	AD0P07	OP07AJ
AD7531	MX7531	AD9685	MAX9685
AD7533	MX7533	AD9686	MAX9686
AD7534	MX7534	AD9687	MAX9687

AD is a registered trademark of Analog Devices Inc.

MAX162-HA5320

Sample-and-Hold Interface



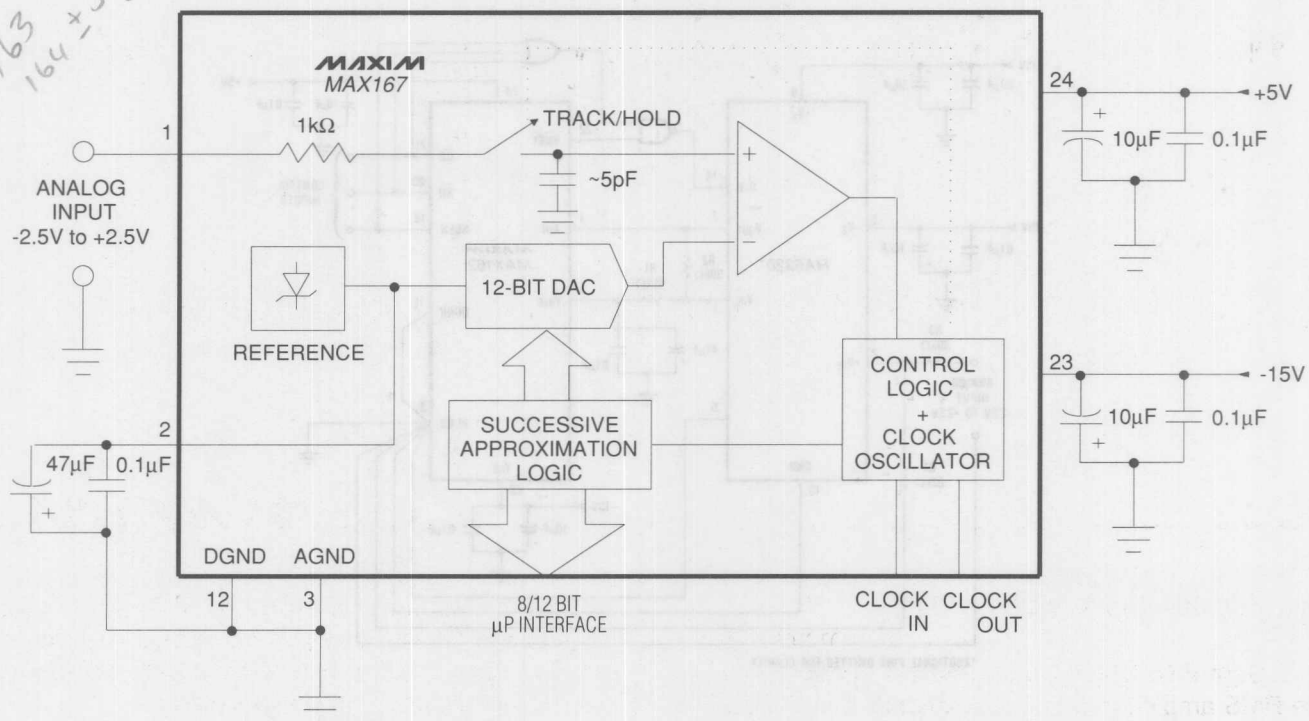
MAXIM

The MAX162/HA5320 combination allows sampling rates up to 210kHz with a conversion time of 3.25µs and an acquisition time of 1.5µs. For a small reduction in speed, a single chip A/D with track-and-hold performs nearly as well.

± \$20

MAX167 Plugs Into The MAX162/MX7572 Socket

MAX163 0-5V INOUT
164 +5V



A MAX167 A/D with an internal track and hold samples at 100kHz. Track-and-hold acquisition time is 1μs and A/D conversion time is 8.33μs, however this includes settling time for the track-and-hold.

The internal track-and-hold is not slew limited like many on-chip A/D track-and-holds and has excellent large signal and wide bandwidth behavior. Exceptionally low 100ps aperture jitter contributes little phase noise.

Dynamic Specifications for A/Ds

**Signal processing applications (DSP)
also need AC (dynamic) specifications**

- SNR - Signal-to-Noise Ratio
- THD - Total Harmonic Distortion
- Peak Harmonic or Spurious Noise

MAXIM

Dynamic Specifications for A/Ds

Signal-to-Noise Ratio (SNR) is the ratio between the RMS amplitude of the fundamental input frequency (signal) and the RMS amplitude of all other A/D output signals (noise). Frequency components up to half the sampling rate are included in the noise sum. This is also sometimes more accurately called "Signal-to-Noise + Distortion". Ideally $SNR = (6.02N + 1.76)dB$, where N is the A/D resolution in bits.

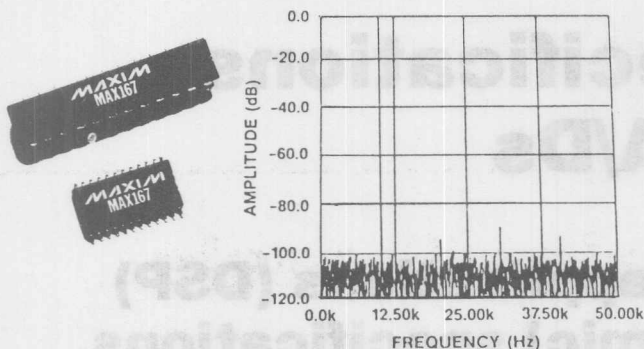
Total Harmonic Distortion (THD) is the ratio of the RMS sum of all harmonics of the input signal (frequencies above DC and below one half the sample rate) to the fundamental itself. This is expressed as:

$$THD = 20\text{Log}[\sqrt{(V_2^2 + V_3^2 + V_4^2 + \dots + V_N^2)}] / V_1$$

where V_1 is the fundamental RMS amplitude and V_2 to V_N are the amplitudes of the 2nd through Nth harmonics.

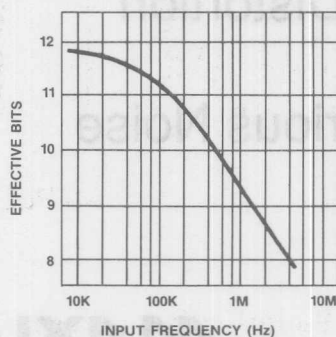
Peak Harmonic or Spurious Noise is expressed as the ratio of the fundamental RMS amplitude to the amplitude of the next largest spectral component (in the frequency band above DC and below one half the sample rate). Usually this peak occurs at some harmonic of the input frequency, but if the ADC is exceptionally linear it may occur only at a random peak in the ADC's noise floor.

THD - Total Harmonic Distortion 10 kHz Sinewave Sampled at 100 kHz



This FFT spectral response plot shows the result of sampling a pure 10kHz sine wave at a 100kHz rate with the MAX167. The 10kHz fundamental and the 2nd through 4th harmonics are seen as the largest spectral components.

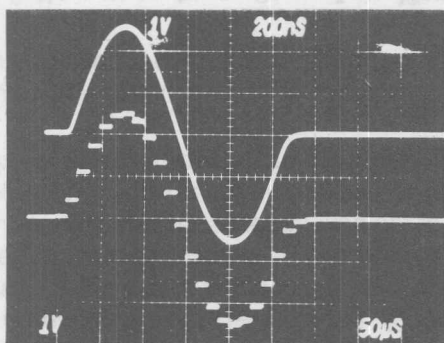
MAX167 Effective Bits vs. Input Frequency



By transposing the equation for SNR, we can determine the effective resolution or the "Effective Number of Bits" :

$$N = \frac{\text{SNR} - 1.76}{6.02}$$

MAX167/177 Undersampling a 1 MHz Sinewave

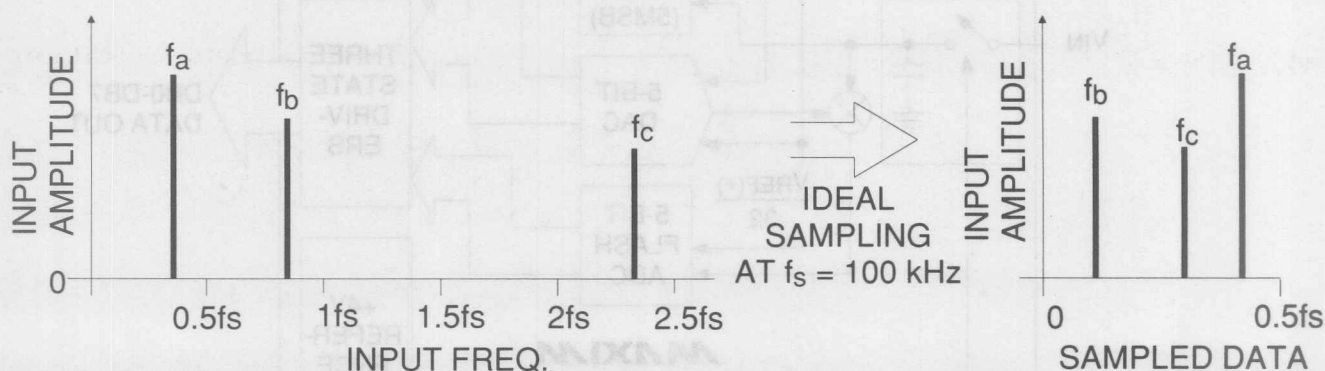


Information can be reconstructed if the converter is able to pass the signal without attenuating high-frequency information. Synchronously under-sampling a sinewave enables the original waveform to be recovered even though its frequency exceeds the sampling rate. The upper trace of the scope photo displays the input signal (1MHz, 200ns/div) while the lower trace reconstructs the signal from the MAX167 A/D output codes (50μs/div).

Must be repetitive

How to use
100KHz A/D
TO use 1MHz ~~sample~~ input signal
MUST BE
REPETITIVE.

Sampling Analog Signals



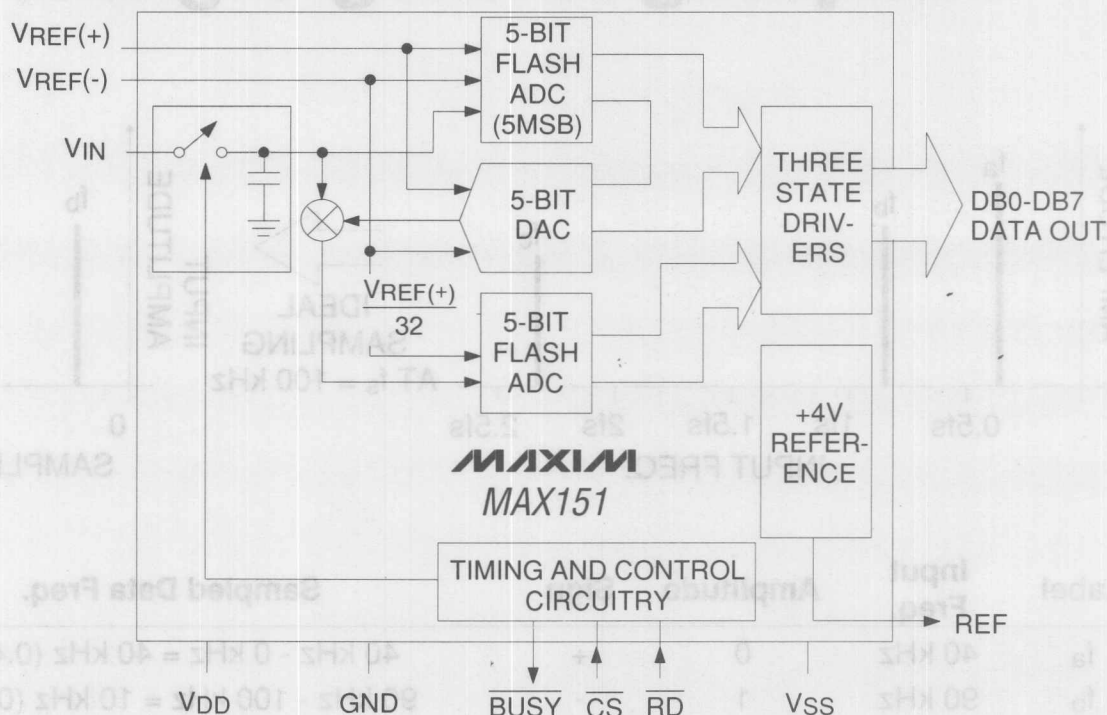
Label	Input Freq.	Amplitude	Sign	Sampled Data Freq.
f _a	40 kHz	0	+	40 kHz - 0 kHz = 40 kHz (0.4 fs)
f _b	90 kHz	1	-	90 kHz - 100 kHz = 10 kHz (0.1 fs)
f _c	230 kHz	2	+	230kHz - 200kHz = 30 kHz (0.3 fs)

MAXIM

Nyquist's criterion mandates that an A/D-converter sample the highest input frequency at least twice per cycle. However, if the input spectral characteristics with respect to the converter's sampling rate are evaluated carefully, a slower (read: less expensive) A/D-converter can be used. The Nyquist theorem also states that signal frequencies above half of the sampling rate may contain aliases.

Sampling three input frequencies f_a, f_b, and f_c at a rate f_s creates a sampled-data spectrum that repeats every f_s/2 hertz. The 0-to-f_s spectrum returned by an FFT thus includes an alias for every input frequency above f_s/2. Filtering the input can effectively remove unwanted aliases.

MAX151 - 1.9 μ s 10-Bit A/D with Ref. + Track/Hold



The MAX151 10-bit half-flash A/D converter uses a bank of 31 on-chip comparators. The analog input is sampled by each comparator input capacitor and compared to a resistive ladder DAC. A 5-bit "coarse" conversion result is then generated from the same ladder DAC and subtracted from the analog input. The difference signal is then compared to a "fine" resistive ladder DAC.

5 coarse and 5 fine bits are then output in 10 bit parallel format.

The input to the MAX151 is tracked and held by on-chip sampling circuitry, eliminating the need for an external track-and-hold. The MAX151 also includes a stable 4.00V reference.

10-Bit A/D Design Guide

	MAX151	MAX173	MAX177
Conversion	Half-flash	SAR	SAR
Resolution (Bits)	10	12	12
No Missing Codes	10	10	10
Speed (max)	1.9 μ s	5 μ s	8.33 μ s
Track-Hold	YES	NO	YES
Input Bandwidth	5MHz*		6MHz*
On-board Reference	+4.00V	-5.25V	-5.00V
Supplies	$\pm$ 5V	+5, -12 to -15V	
Pinout shared		MAX162	MAX167
Replaces		AD7572	

*Undersampled

MAXIM

Reduced versions

12-Bit A/Ds Compared

	MAX162 MX7672	MAX163/4/7	MAX174 MX574A/674A	MAX178
Conv. Time	3 μ s	8 μ s	8 μ s	100 μ s
Input Range	+5V	+5/+10V or $\pm$ 5V	+10/+20V or $\pm$ 5/ $\pm$ 10V	+5V
Reference	YES (EXT. MX7672)	YES	YES	YES
Autozero	NO	NO	NO	YES
Zero Error	$\pm$ 3 LSB	$\pm$ 4 LSB	$\pm$ 1 LSB	1/4 LSB
Supply (V)	+5, -12 to -15		+5, $\pm$ 12 to $\pm$ 15	$\pm$ 5, $\pm$ 15
Replaces	MX7572+ T/H			

MAXIM

OFFSETS ETC.

AUTO CALIBRATION - NO TRIMMING REQ'D

MX = AD

Maxim Multi-channel Analog-to-Digital Converters

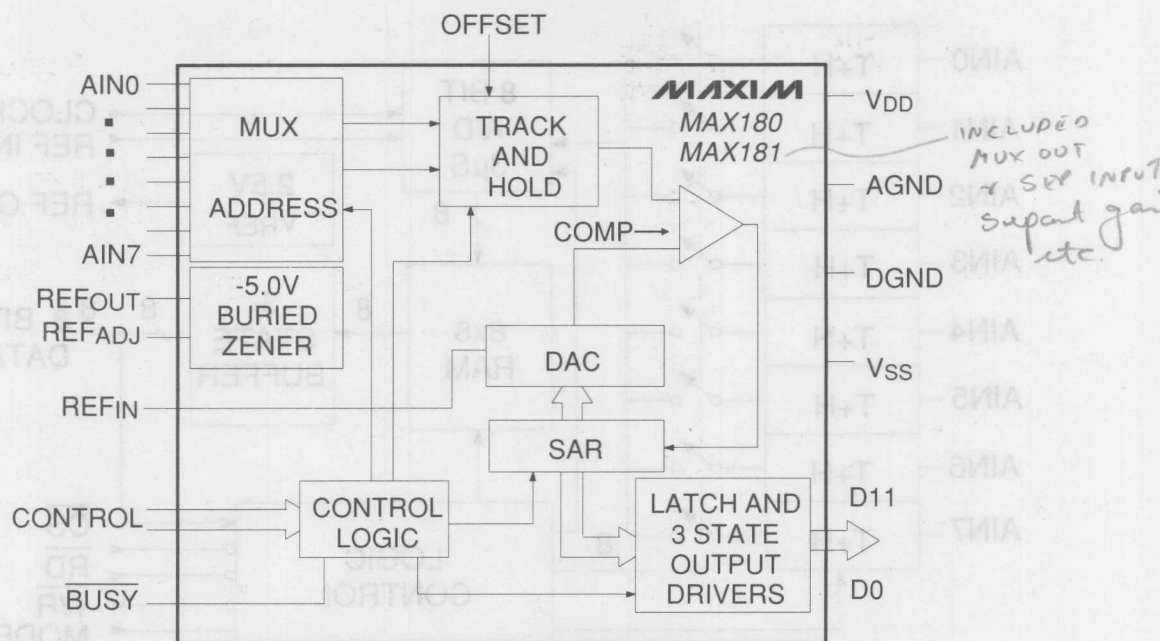
Part#	Resolution (Bits)	Speed μ sec	Channels	Track + Hold	Ref included	Features
MAX133	16+	50ms	7	NO	NO	± 40000 counts
MAX154/158	8	2.5	4/8	YES	YES	Replaces MX7824/7828
*MAX155/156	8	2.5	4/8	YES	YES	8 track + holds on chip
MAX161	8	20	8	NO	NO	8X8 RAM
*MAX180/181	12	6	8/6	YES	YES	Also differential input
*MAX182	12	100	4	YES	YES	Replaces MX7582
*MX7582	12	100	4	NO	NO	Upgrade with MAX182

*These part numbers not listed in 1989 Data Book

MAXIM

MAX180, MAX181-12-Bit One Chip Multi-Channel A/D

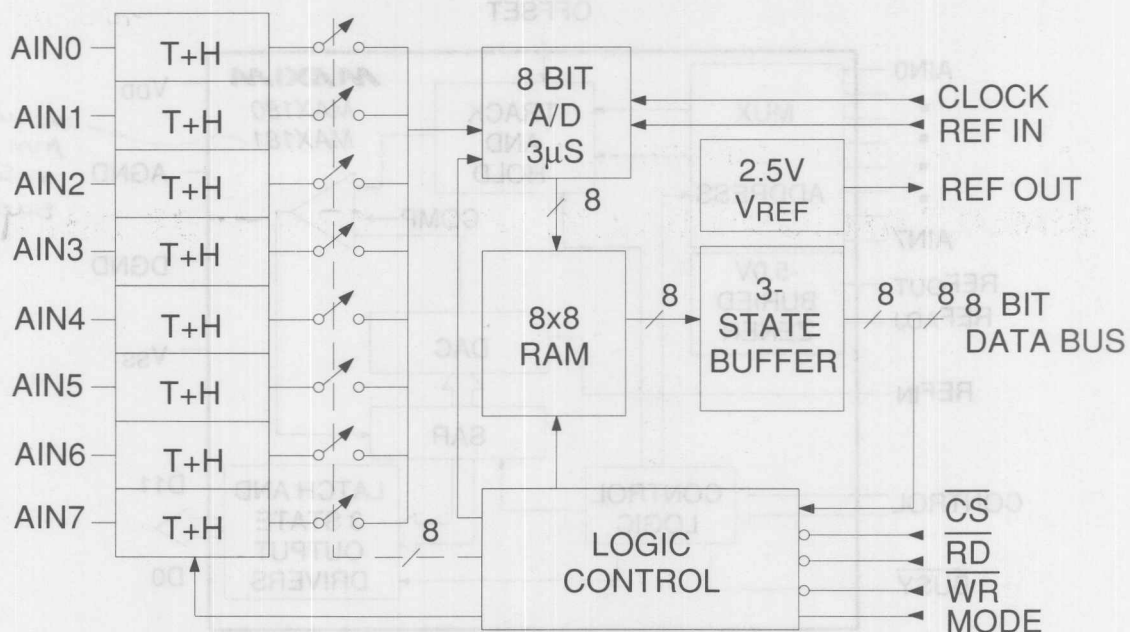
Complete Analog Front End



The MAX180 and MAX181, complete 12-bit Data Acquisition Systems (DAS), offer 8 and 6 channel input multiplexers. They include a high bandwidth track-and-hold, 6 μ s A/D, low drift reference, and a flexible 8- or 16-bit microprocessor interface. A microprocessor can configure the MAX180 and MAX181 for unipolar or bipolar input conversion as well as for single-ended or differ-

ential inputs for each channel. Both parts sample and digitize at a 100kHz rate. On the analog side, an internal or external reference can be used. The internal reference value and the zero offset are adjusted through two high impedance inputs, simplifying system trims. Analog drive requirements are also simplified with high impedance MUX channel inputs.

MAX156 8-Channel 8-Bit A/D Simultaneous T/H With 8X8 RAM



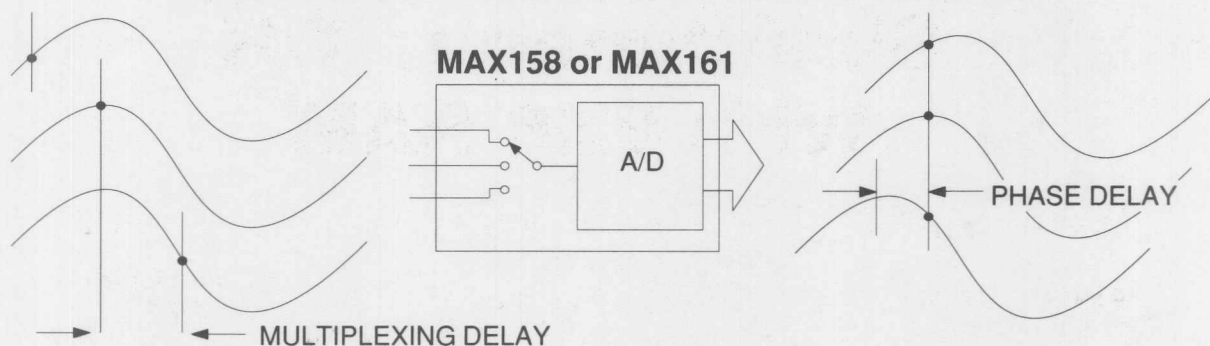
MAXIM

MAXIM offers several 8 bit data acquisition systems which combine an 8 channel mux with an 8 bit A/D. The MAX158 combines a reference and 2.5µs A/D with a track-and-hold (T+H). The MAX161's 8 channel mux continually scans all inputs while each conversion result enters an 8X8 RAM location where it is read by a µP. No track-and-hold is included on the MAX161.

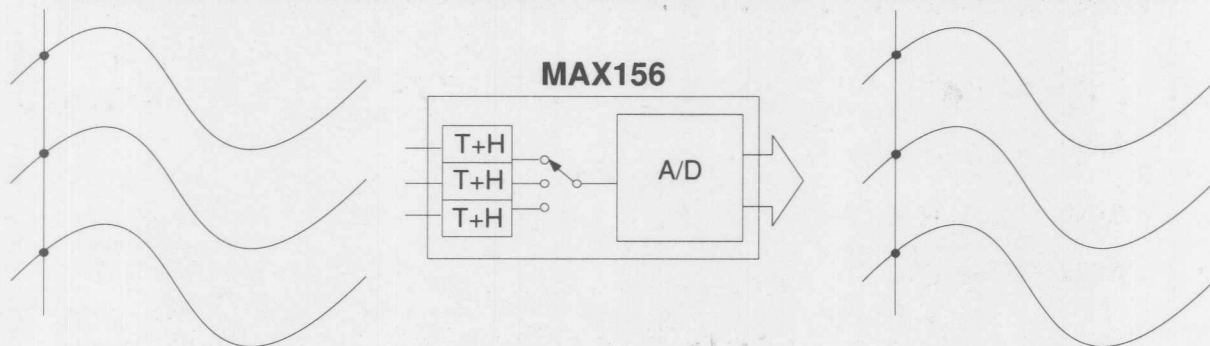
The MAX158, 161 and other muxed A/D converters sample only one input at a time. The mux is advanced to

the subsequent channel after each conversion. A "time skew" or phase delay exists between channels since they can't be measured at the same instant. In applications where such phase errors can't be tolerated, a separate T+H is needed for each channel, in front of the mux. All signals are then sampled simultaneously, and then sequentially converted to digital data by the A/D. Another possible solution uses 8 synchronized A/D converters, but this gets expensive.

MULTIPLEXING A/D = PHASE DELAY



SIMULTANEOUS SAMPLING = NO PHASE DELAY



MAXIM

The MAX156 includes 8 T+Hs on chip to eliminate relative timing errors by simultaneously sampling all input channels. This is useful for a variety of signal measurement functions such as vibration analysis, transient event recording, and other phase sensitive multi-signal applications. Eight track-and-holds are configurable in several combinations of single and differential inputs. The

MAX155 has 4 inputs which are also configurable. The mux normally sequences through all channels and then repeats. However, the number of scanned channels may be reduced to shorten the channel update time. For example, if only 5 of 8 channels are scanned, the update time per channel drops from 24 μ s to 15 μ s.

APPLICATIONS

POWER SUPPLY
DC-DC CONVERTERS

A/D CONVERTERS

ACTIVE FILTERS

■ Serial Apps

■ Lower Noise

DACS REFERENCES

■ Serial Applications

RS-232

■ Isolation

μP SUPERVISORY
CIRCUITS

MAXIM

DACs

RESOLUTION

8 BIT

V OUT

- MX7224
- MX7225 (Quad)
- MX7226 (Quad)
- MX7228 (Octal)
- MAX500 (Quad, Serial)

I OUT

- MX7523
- MX7524
- MX7528 (Dual)
- MX7628 (Dual)
- MAX7624

10 BIT

I OUT

- MX7520
- MX7530
- MX7533

12 BIT

V OUT

- MX7245 (Ref)
- MX7248 (Ref)
- MX7845 (MDAC)
- MAX501 (MDAC)

I OUT

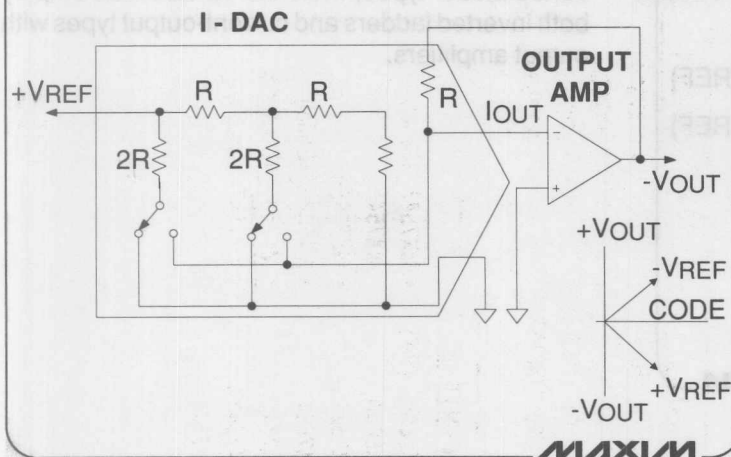
- MX565A (Ref)
- MX566A
- MX7521
- MX7531
- MX7541
- MX7541A
- MX7542
- MX7543 (Serial)
- MX7545
- MX7545A
- MAX543 (Serial)
- MX7537 (Dual)
- MX7547 (Dual)

14 BIT

I OUT

- MX7534
- MX7535
- MX7536
- MX7538

CMOS Voltage DAC Designs - I



ADVANTAGES

- Constant Load on $V_{REF}(=R)$
- V_{REF} can be Bipolar
- 2 Quadrant Multiplying

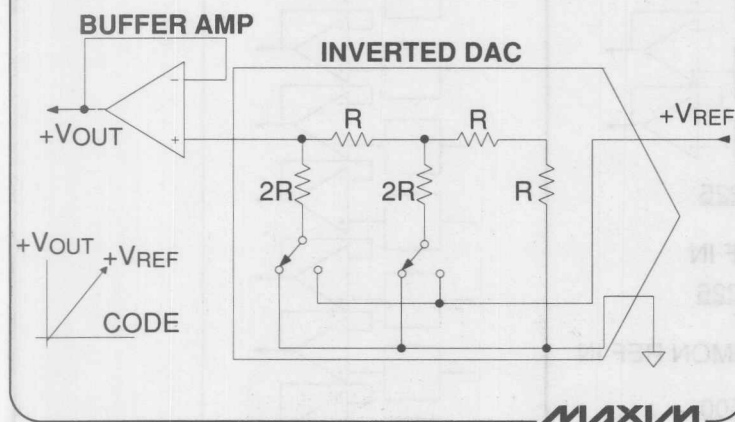
DISADVANTAGES

- V_{OUT} inverted from V_{REF} (V_{IN})
- 2 power supplies

Current Output DAC with Amplifier - Standard DAC configurations use an R-2R ladder where current flowing into the reference input is divided between the I-OUT and I-OUT outputs. Usually this current is converted to a voltage by an op amp. Most I-DACs require an external op amp, however the new MAX501 and MX7845, 12 bit CMOS DACs, include this op amp on the chip.

The reference input can be positive, negative, or an AC signal with respect to ground, however the op amp output is of opposite sign to the reference so two power supplies ($\pm$) are usually needed. These DACs are often called MULTIPLYING DACs since the reference input is multiplied (attenuated) by the digital input code.

CMOS Voltage DAC Designs - II



ADVANTAGES

- Single power supply
- V_{REF} , V_{OUT} both positive

DISADVANTAGES

- Load on V_{REF} varies
- Only positive V_{REF}

Voltage Output (Inverted Ladder) with Buffer - In this voltage output architecture, the DAC ladder is inverted and acts as voltage divider rather than a current divider. This allows operation with one power supply. Also, The output and reference are the same polarity.

Multiplying applications are not as convenient as with I-DAC configuration, since negative reference inputs are not feasible. Unity gain buffers are incorporated on chip to provide a low impedance voltage output. The MX7228 has 8 such buffered DACs on one IC.

Voltage Output DACs

- ☐ Inverted DAC with Buffer
☒ Current DAC with Amplifier

8 Bit V_{OUT}

☐ MX7224	☐ MX7245 (INTERNAL REF)
☐ MX7225 (QUAD)	☐ MX7248 (INTERNAL REF)
☐ MX7226 (QUAD)	
☐ MX7228 (OCTAL)	☒ MX7845
☐ MAX500 (QUAD SERIAL)	☒ MAX501

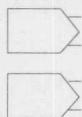
12 Bit V_{OUT}

This table identifies which Maxim voltage output DACs fall into the two families discussed in the previous two slides. The 8-bit devices are all inverted ladder types, while the 12-bit DACs employ both inverted ladders and current-output types with output amplifiers.

MAXIM

MULTIPLE DACs

DUAL I-DAC

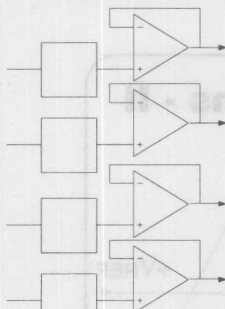


MX7528
 8 BIT
MX7628
 8 BIT TTLIN

MX7537
 12 BIT
 12 BIT LOAD

MX7547
 12 BIT
 8 + 4 BIT LOAD

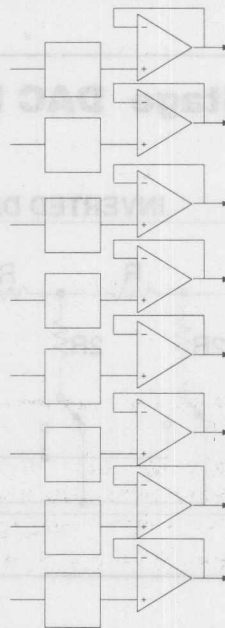
QUAD V-DAC



MX7225
 8 BIT
 4 REF IN
MX7226
 8 BIT
 COMMON REF IN

MAX500
 8 BIT
 3 REF IN
 SERIAL LOAD

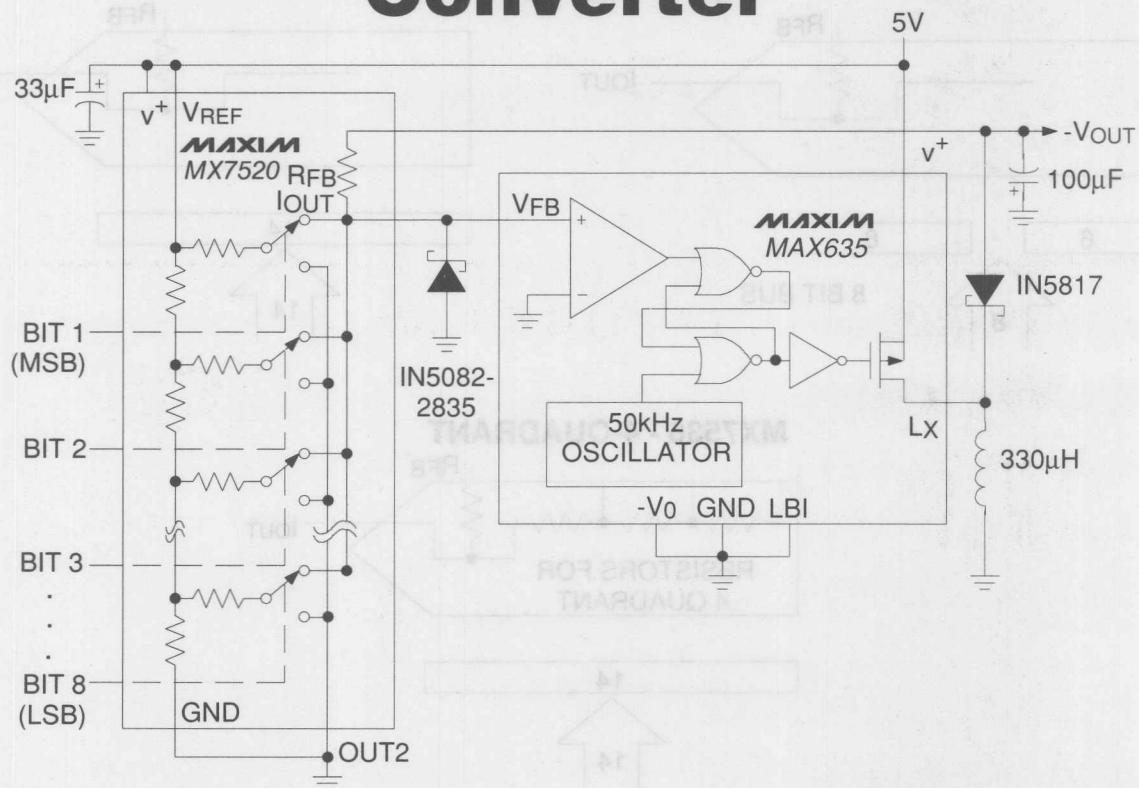
OCTAL V-DAC



MX7228
 8 BIT
 COMMON REF IN

MAXIM

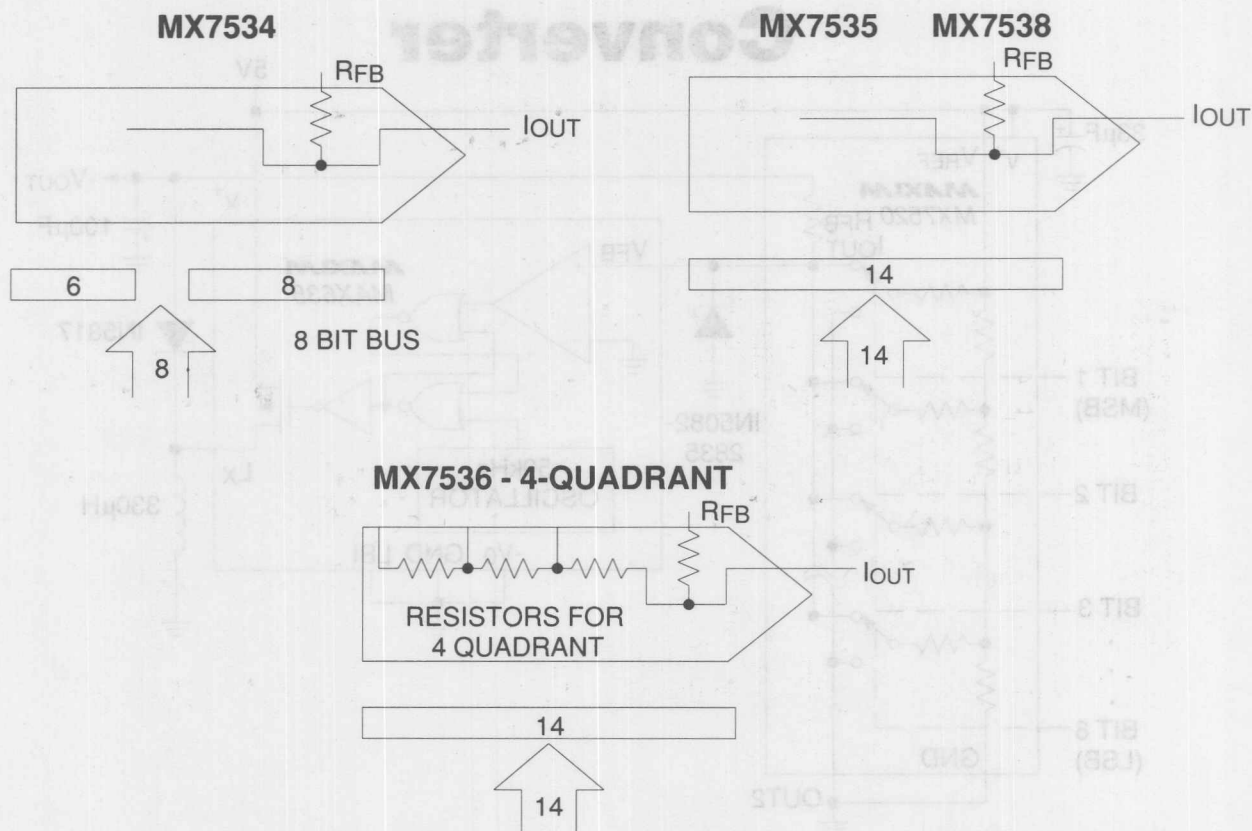
DAC Controls DC-DC Converter



You can digitally adjust the otherwise fixed output voltage of a switching regulator by connecting a DAC in the regulator's feedback path. The regulator circuit shown here provides a variable output from 0 to -5V and can

deliver 25mA. Changing the DAC code changes the voltage division ratio between the output and the feedback pin in a manner similar to a potentiometer.

14 Bit I-DACs



MAXIM

Maxim makes 4 different versions of CMOS 14 bit I-DACs. The MX7534 interfaces with 8 bit data buses, while the other 3 work with 16 bit buses. The MX7536

includes all feedback and scaling resistors on-chip for true 4-quadrant multiplying applications.

REFERENCES

VOLTAGE OUT

1.2 Volts

- **ICL8069**
(10-100ppm/°C)

2.5 Volts

- **MX580**
(10-85ppm/°C)
- **MX584**
(10-30ppm/°C)

5.0 Volts

- **MAX675**
(12-20ppm/°C)
- **REF02**
(8.5-250ppm/°C)
- **MX584**
(5-30ppm/°C)

7.5 Volts

- **MX584**
(5-30ppm/°C)

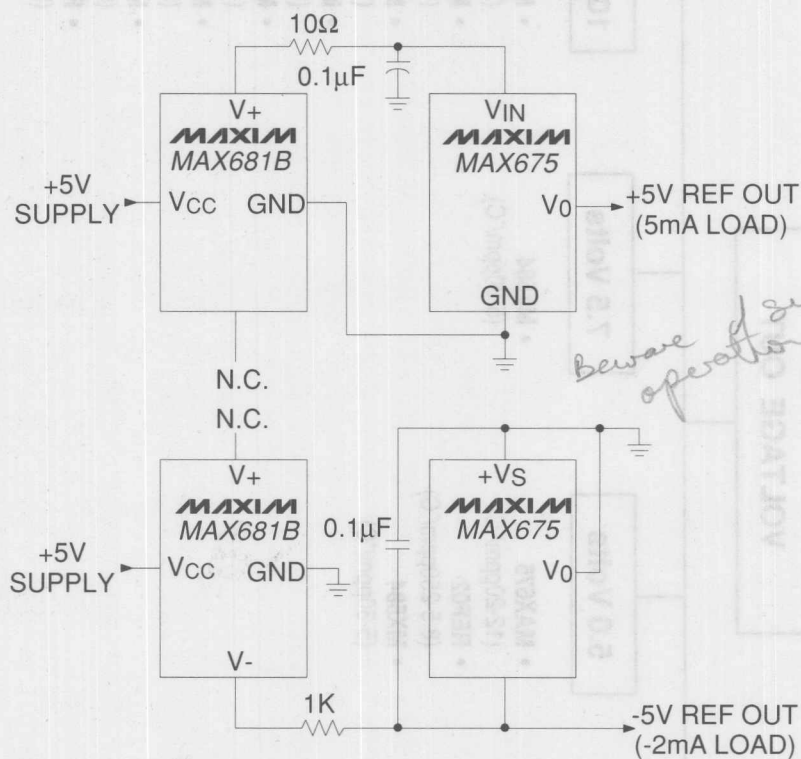
10.0 Volts

- **MAX670**
(3-10ppm/°C)
- **MAX671**
(1-10ppm/°C)
- **MAX674**
(12-20ppm/°C)
- **MX2700**
(3-10ppm/°C)
- **MX2710**
(1-5ppm/°C)
- **MX581**
(5-30ppm/°C)
- **MX584**
(5-30ppm/°C)
- **REF01**
(8.5-65ppm/°C)

-10.0 Volts

- **MX2701**
(3-10ppm/°C)

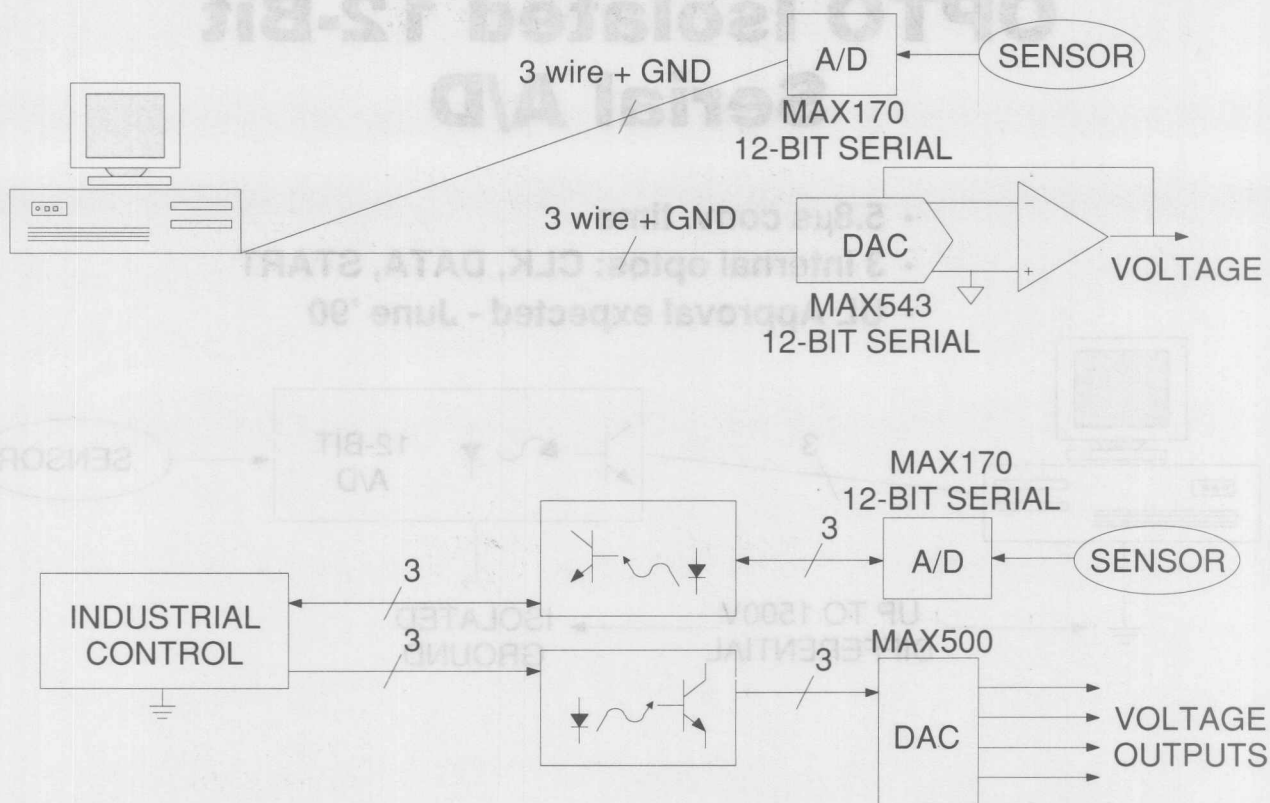
± 5V References From +5V Supply



It is possible to make a +5 volt reference from a +5 volt supply, i.e. with no headroom. This circuit uses a dual charge pump circuit with built-in capacitors, the MAX681, to produce +10 and -10 volts. The +10 volt output can

power a +5 volt reference such as the MAX675 which requires a minimum of 8 volts to properly regulate. The -10 volt power output powers the MAX675 as a -5 volt reference when connected as shown in the lower picture.

Serial A/D and DAC



MAXIM

Serial digital communication is preferable to parallel when long distances are involved. The MAX170 is a 12-bit 5.6 μ s serial output A/D. Only three signal lines are needed. The MAX543 12-bit serial input DAC and also requires only 3 signal wires. Both devices come in 8-pin packages.

In many industrial control situations, isolation is required between the computer/controller and an A/D or DAC. With serial data converters, this is easily accom-

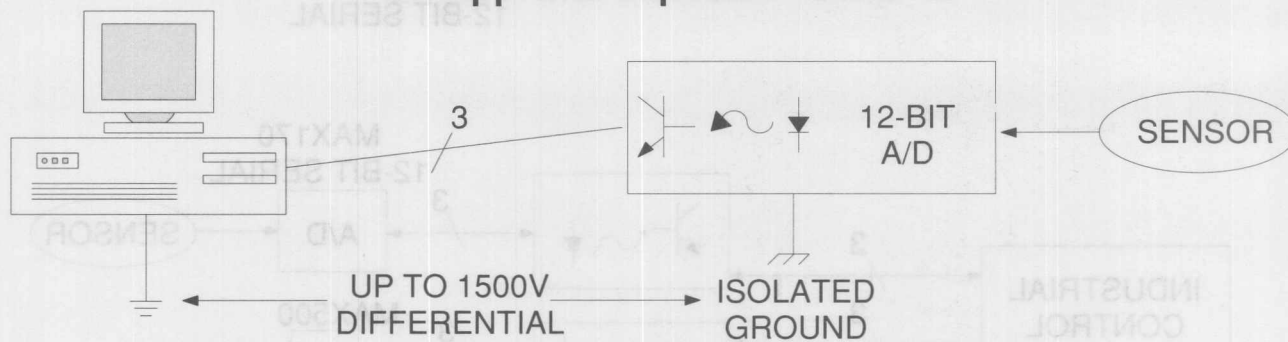
plished with high speed opto-isolators. Isolation allows the A/D or DAC to operate at a different potential than ground and also to reject noise induced on ground lines by heavy current surges from motors, heaters, and other industrial electrical equipment.

The MAX500 is a quad serial, 8-bit voltage-output DAC. Serial data lines can be cascaded with other MAX500s, without the need for additional control lines.

MAX171

OPTO Isolated 12-Bit Serial A/D

- 5.8 μ s conv. time
- 3 internal optos: CLK, DATA, START
- UL Approval expected - June '90



MAXIM

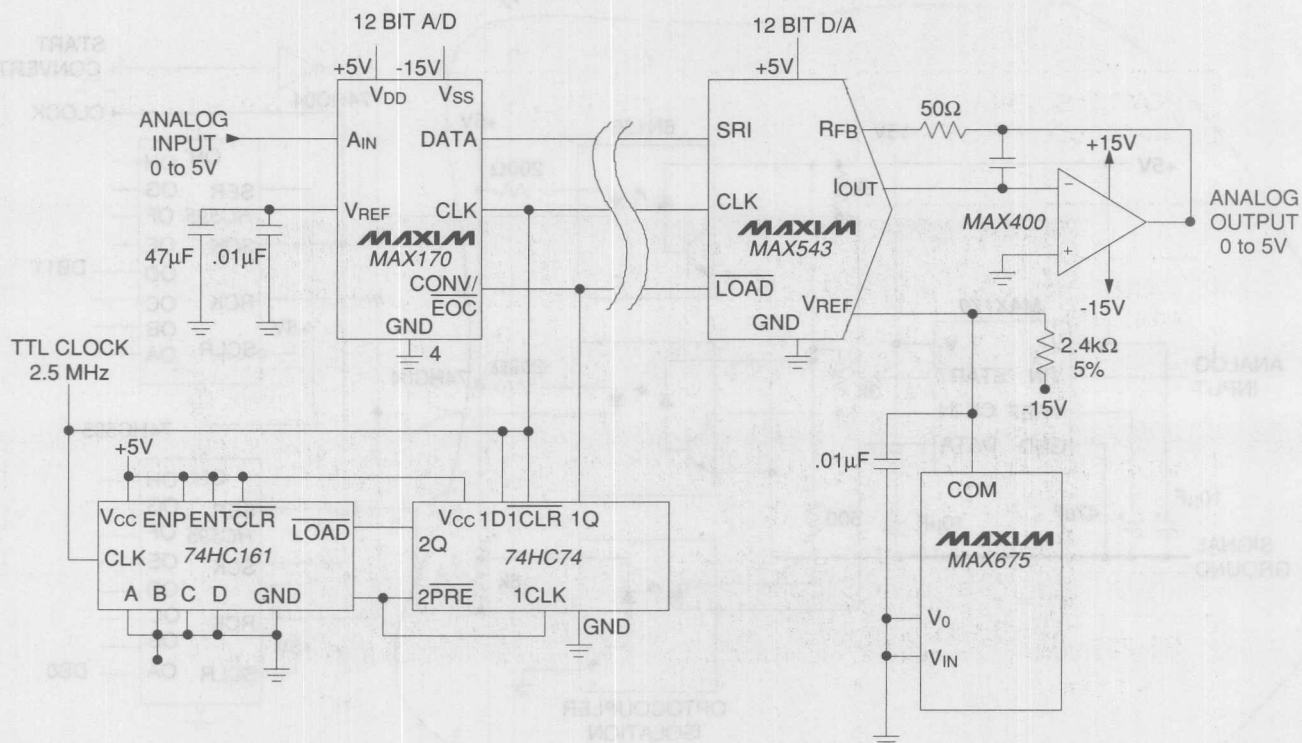
The MAX171 makes the job of isolation much easier by including 3 opto-isolators (for clock, convert start, and data) on board in a standard 16 pin DIP package.

MAXI 71



MAX170/MAX543

Serial Digital Interface



The MAX170 12-bit A/D and the MAX543 12-bit DAC, both with serial digital interfaces, can talk to each other without help from a μ P. A 4-bit counter and a dual D-type flip-flop manage the interface. This is useful where

low level signals (such as thermocouple or transducer signals) must be transmitted through noisy environments. If opto-isolators are added, a "digital" isolation amplifier can be made.

APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLEXERS

- Input

ANALOG SWITCHES MULTIPLEXERS VIDEO PRODUCTS

VIDEO PRODUCTS

- Cross

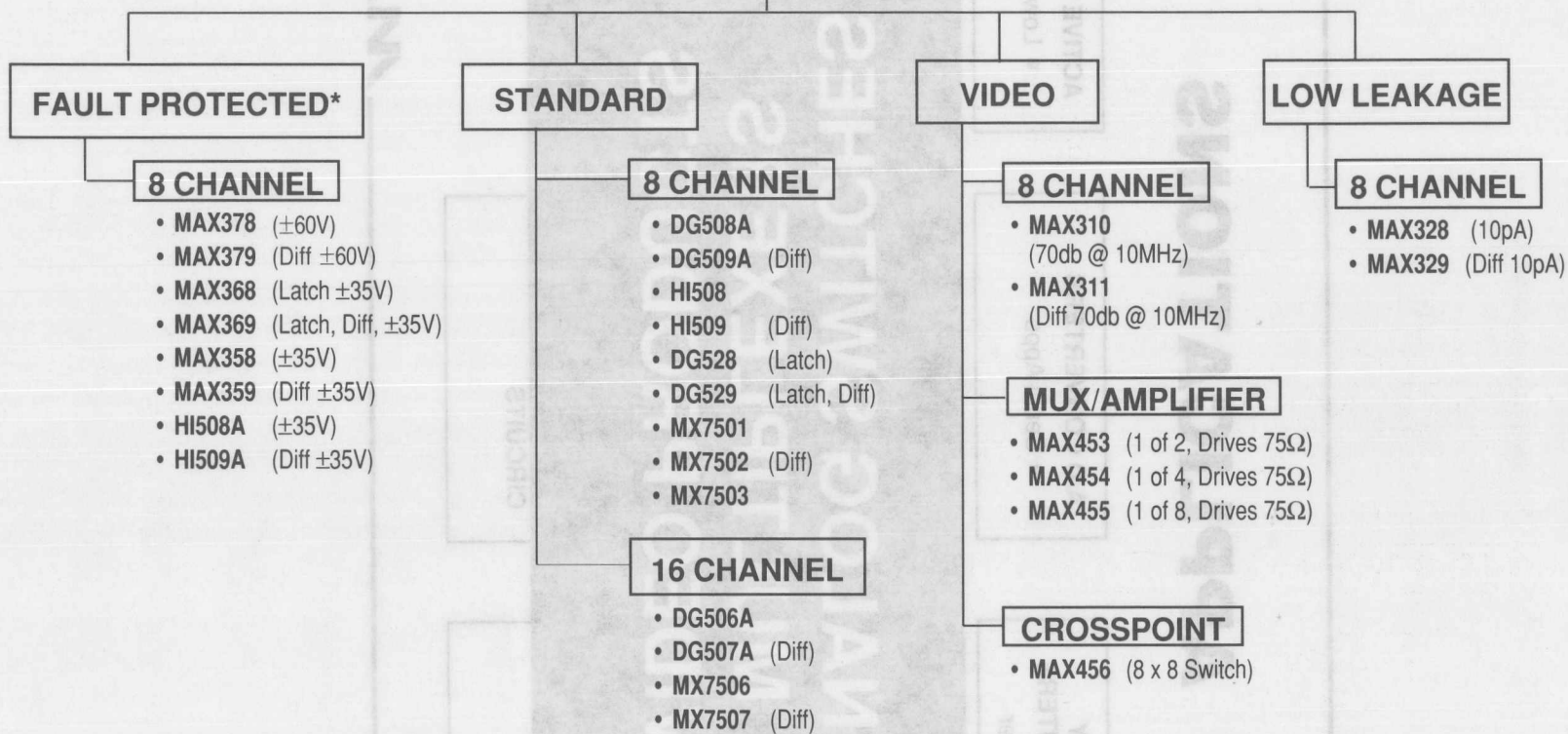
RS-232

- Isolation

CIRCUITS

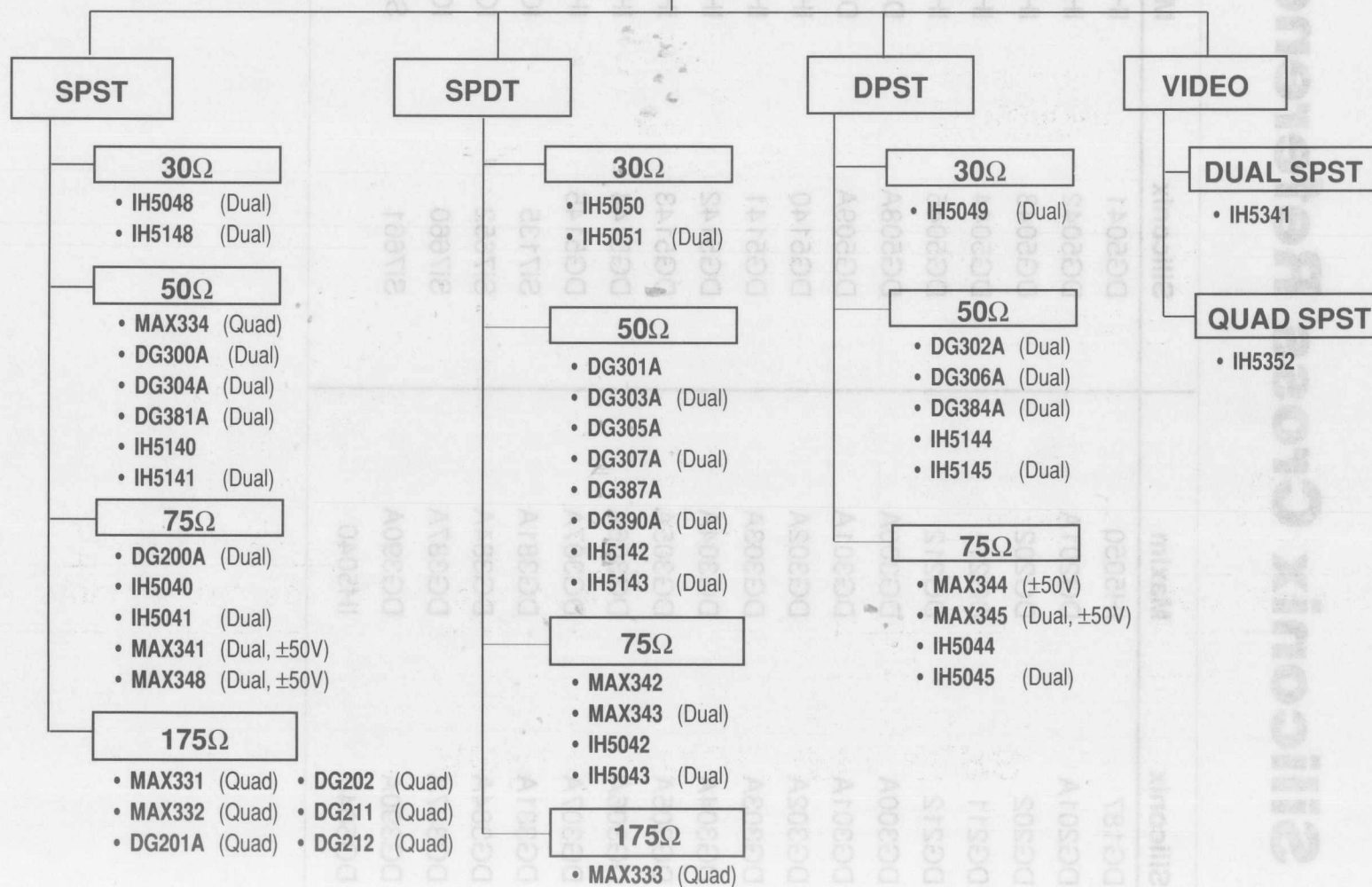
MAXIM

ANALOG MULTIPLEXERS



* Withstands quoted input or output voltage indefinitely with/without supply voltage present.

ANALOG SWITCHES



Siliconix Cross Reference

Siliconix	Maxim	Siliconix	Maxim
DG187	IH5050	DG5041	IH5041
DG201A	DG201A	DG5042	IH5042
DG202	DG202	DG5043	IH5051
DG211	DG211	DG5044	IH5044
DG212	DG212	DG5045	IH5045
DG300A	DG300A	DG508A	DG508A
DG301A	DG301A	DG509A	DG509A
DG302A	DG302A	DG5140	IH5140
DG303A	DG303A	DG5141	IH5141
DG304A	DG304A	DG5142	IH5142
DG305A	DG305A	DG5143	IH5143
DG306A	DG306A	DG5144	IH5144
DG307A	DG307A	DG5145	IH5145
DG381A	DG381A	Si7135	ICL7135
DG384A	DG384A	Si7652	ICL7652
DG387A	DG387A	Si7660	ICL7660
DG390A	DG390A	Si7661	Si7661
DG5040	IH5040		

New Analog Multiplexers

INPUT PROTECTED

- $\pm 60\text{V}$ (120Vp-p) Fault Protection

MAX378 1 of 8 channels

MAX379 2 of 8 Differential

- $\pm 35\text{V}$ (70Vp-p) Fault Protection

MAX358 1 of 8 channels

MAX359 2 of 8 Differential

MAX369/368 With Latches

ULTRA LOW LEAKAGE MUX - MAX328/329

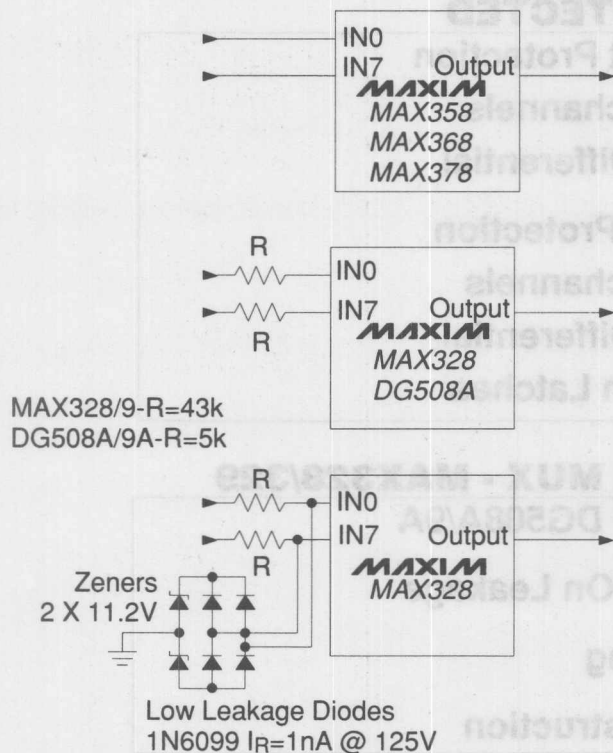
- Pin Compatible With DG508A/9A
- 1pA Typical Off and On Leakage
- 2% $R_{DS(ON)}$ Matching
- Latch-Up Proof Construction

MAXIM

The MAX378/379 protection structure (series N-Channel, P-Channel, N-Channel) allows over-voltage signals on both input and output pins. This is not the case with other manufacturers' fault protected multiplexers which are current limited at the channel inputs only. With the MAX378/379, Maxim has increased protection levels to $\pm 60\text{V}$ at any mux input or output, and current flow under over-voltage conditions is limited to only nanoamps.

The MAX328/329 8-channel multiplexers have the lowest input leakage current of any manufacturer. Guaranteed $I_{DS(off)}$ is 1pA (MAX359M). Low input leakage allows high value series resistors to be placed in series with channel inputs, affording another means of high voltage input protection.

Input Protection Schemes



- Fewest components
- $\pm 60\text{V}$ Protection - MAX378
- $\pm 35\text{V}$ Protection - MAX358, MAX368
- Hi Impedance Inputs and Output with power off
- No off-channel over load error

- 1pA Input Leakage Current MAX328
- Input Protection beyond Supply Voltage $\pm 240\text{V}$ - MAX328/329
- $\pm 50\text{V}$ - DG508A/509A

- No off-channel over load error
- Same Input protection as above levels

MAXIM

3 input protection schemes are outlined:

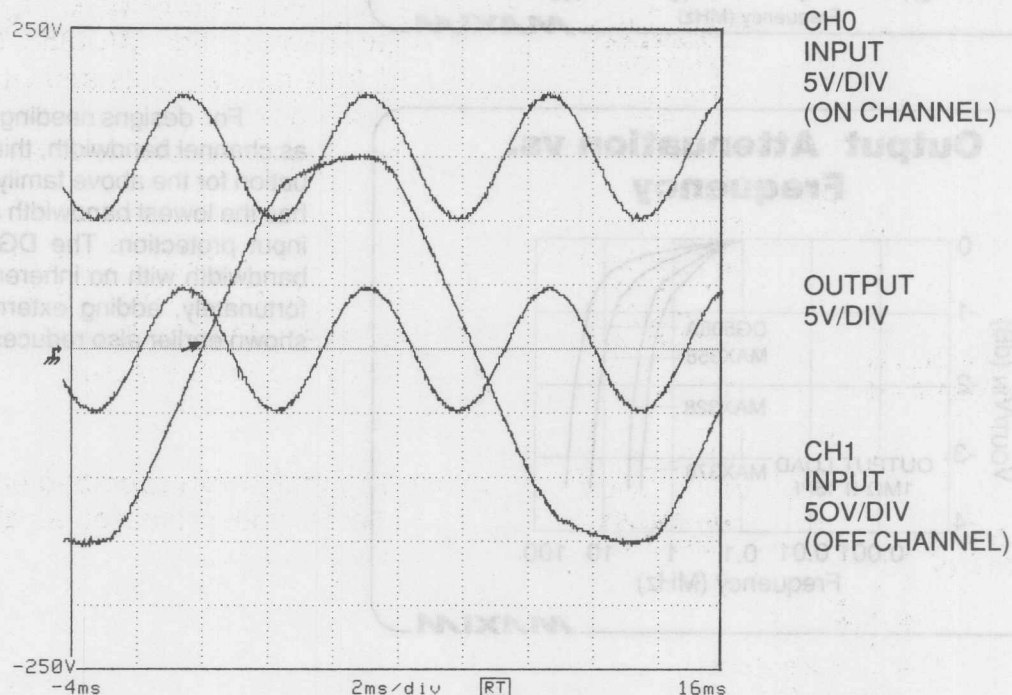
1) Input protected multiplexers (MAX358/68/78) with no external components - This solution performs best up to the over drive rating of the multiplexer ($\pm 60\text{V}$ for MAX378).

2) Standard (DG508A) and low leakage (MAX328) muxes with external input resistors - Allows higher voltage pro-

tection but over-driven OFF channels may interfere with normal ON channels.

3) Standard and low leakage muxes with external clamp networks - Uses addition circuitry but prevents interference from over-driven channels.

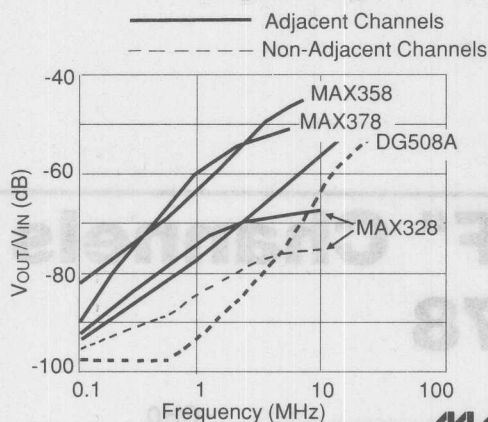
Overdriving "OFF" Channels MAX378



To demonstrate the ruggedness of the MAX378, channel 1 is over-driven with a 150V AC signal (almost, but not quite, AC line voltage levels)! This is nearly 2.5 times the multiplexer's maximum rating, and it is not guaranteed that all devices will withstand this. This mux

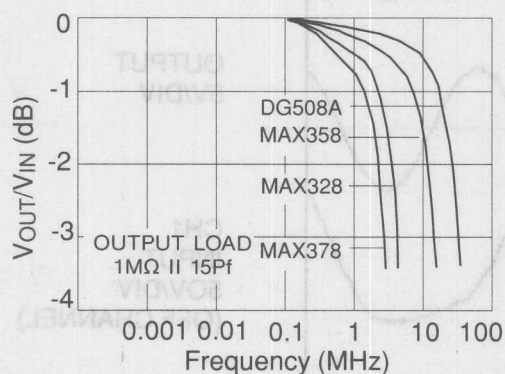
not only survives this treatment, but an adjacent "ON" channel (channel 0) and the output signal (5V sinewave) are unaffected while channel 1 is being abused in this manner.

Multiplexer Crosstalk vs. Frequency



The MAX328, MAX358, and MAX378 are all pin-compatible with the DG508A. Here comparative AC performance data is plotted for these parts under similar conditions. The first plot is of Crosstalk vs. Frequency between adjacent channels for each of the parts. On the same graph is Crosstalk vs. Frequency when the A0 address line is grounded and the multiplexer is used as a 1 of 4. This way only alternate channels are used and isolation performance improves. Keep in mind also that Maxim's MAX310/311 and MAX453/4/5 multiplexers, though not pin-compatible with the DG508, have guaranteed high frequency isolation specifications.

Output Attenuation vs. Frequency



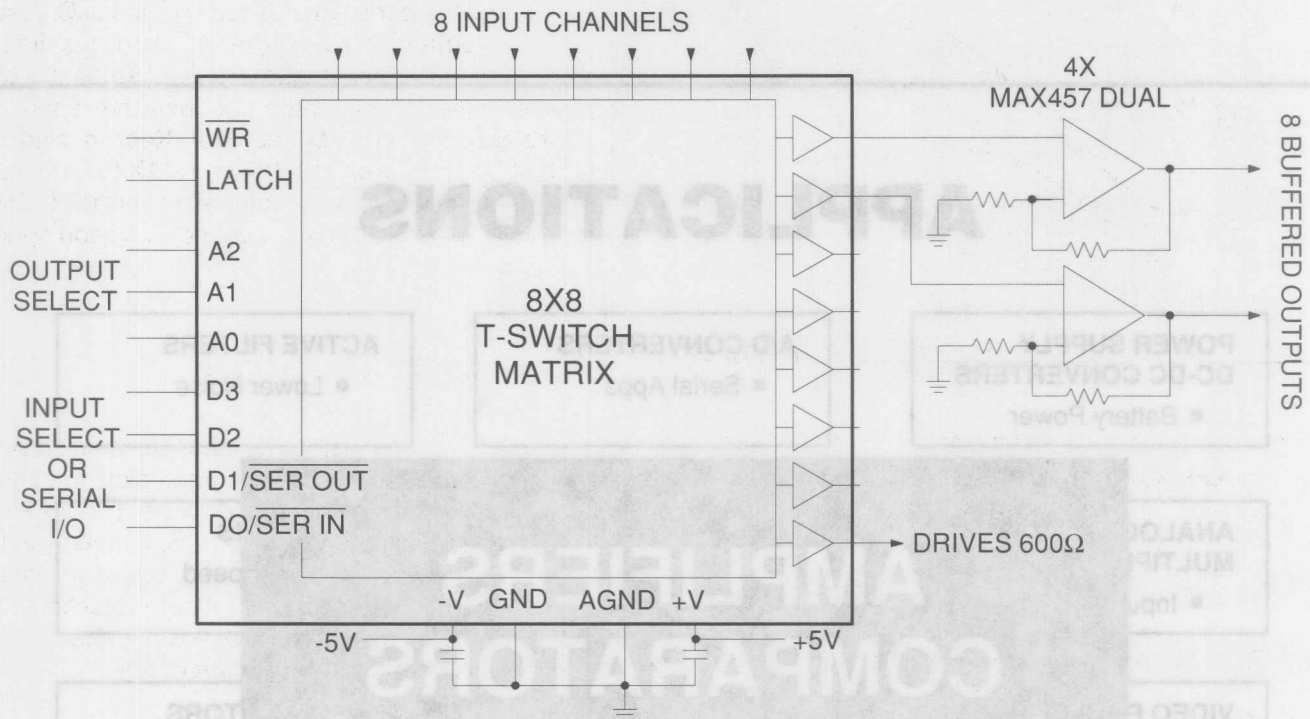
For designs needing input protection as well as channel bandwidth, this graph plots the attenuation for the above family of parts. The MAX378 has the lowest bandwidth and the highest level of input protection. The DG508A has the highest bandwidth with no inherent input protection. Unfortunately, adding external input protection as shown earlier also reduces bandwidth.

Mux and Switch Performance With $\pm 5V$ Supplies

- 1/3 Supply Current of $\pm 15V$
- $<1\mu A$ Supply Current with Rail-to-Rail Logic Levels
- 1/2 Switch Leakage current of $\pm 15V$
- TTL Compatibility remains
- 2 to 3X R_{ON} Increase
- 2 to 3X Switch Delay Increase

Nearly all of Maxim's standard switch and multiplexer products will operate with $\pm 5V$ supplies. This table outlines the performance differences to be expected as compared to $\pm 15V$ operation. Device data sheets also supply performance data with other than $\pm 15V$ power in many cases.

MAX456 8X8 Crosspoint



MAXIM

The MAX456 has an 8x8 "T-switch" matrix arranged for 8 input and 8 output channels. Each output can drive 400Ω and 20pF to 1.2V. Switch configuration data is loaded into the MAX456 one of three ways: 1) as a 7-bit parallel word, 2) as a 7-bit serial word, and 3) as a 32-bit

serial stream. Each of the 8 output channels may be connected to any one input channel. The MAX456 outputs also conveniently drive MAX457 dual amplifiers so that 75Ω loads can be driven with minimum components.

MAX456 Video Crosspoint

- Buffered Output 8X8 Crosspoint Switch
- -3 dB Gain Bandwidth -30MHz
- 80 db Channel Isolation @ 5MHz
- High Impedance Inputs
- 2pF Input Capacitance
- Unity Gain Stable
- No External Compensation Needed
- 40 Lead Package

MAXIM

APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLIERS

- Input

VIDEO P

- Cros

RS-232

- Isolation

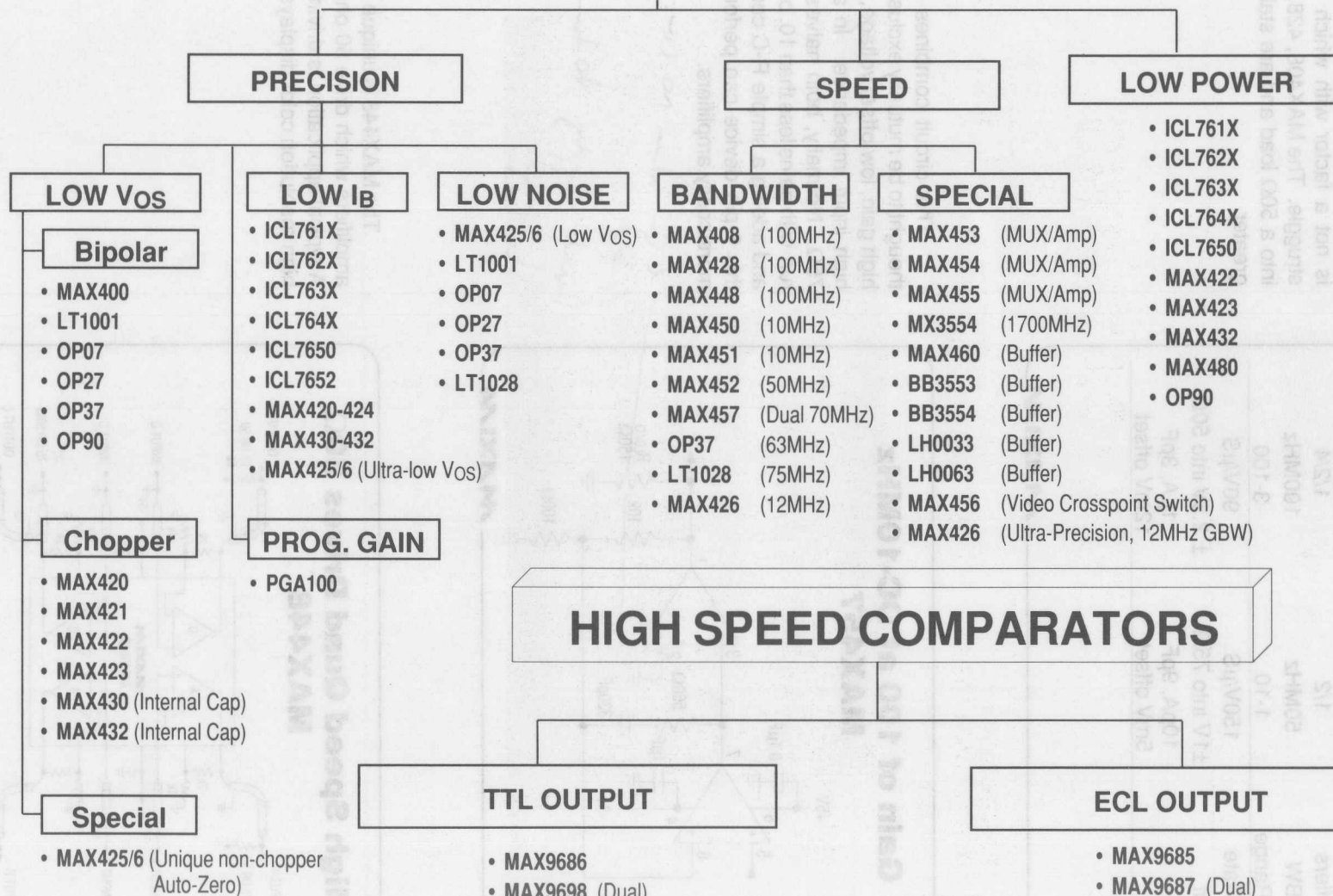
CIRCUITS

AMPLIFIERS COMPARATORS

- High Speed

MAXIM

AMPLIFIERS



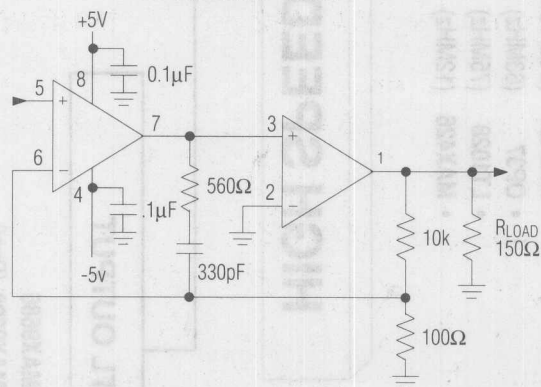
New Video Amplifiers

	MAX452/457	MAX408/428/448
Amplifiers	1/2	1/2/4
Gain-BW	50MHz	100MHz
Gain Range	1-10	3-100
Slew Rate	150V/ μ S	90V/ μ S
Output	± 1 V into 75 Ω	± 2.5 V into 50 Ω
Input	10pA, 9pF 5mV offset	1 μ A, 3pF 12mV offset

MAXIM

The MAX452 and MAX457 (dual) video amplifiers directly drive 75 Ω loads and are unity gain stable. The MAX453/54/55 have input multiplexers with 2/4/8 channels. By buffering the mux output with an internal buffer, switch on resistance is not a factor with which the designer has to struggle. The MAX408, 428, and 448 drive 50mA into a 50 Ω load and are stable with gains of 3 or greater.

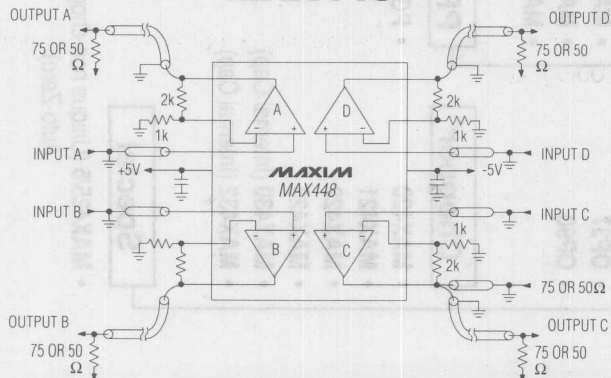
Gain of 100 at DC-10MHz MAX457



MAXIM

This circuit combines characteristics often thought to be mutually exclusive in amplifiers: very high gain, low offset voltage, high bandwidth, and high input impedance. In addition, it can drive 75 Ω . Normally, both halves of the MAX457 are run with gains less than 10, but by cascading them and adding a simple R-C compensation network, this 8-pin device can perform as well as much more costly amplifiers.

High Speed Quad Drives 50 Ω MAX448



MAXIM

The MAX448 is unique in that it contains four amplifiers which drive 50 ohm loads on one chip. A typical application is driving RGB plus Sync for high resolution color displays.

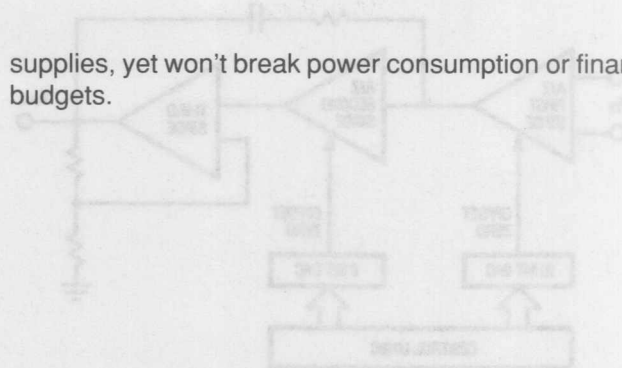
Low Power Precision Op-Amps

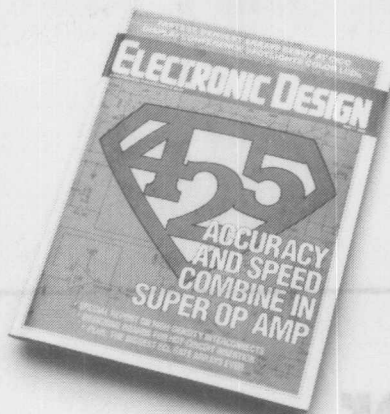
	MAX480	MAX432 (No External Caps)	MAX422	MAX425
Input Offset	70 μ V max	5 μ V max	10 μ V max	1 μ V max
Drift	0.3 μ V/ $^{\circ}$ C	0.02 μ V/ $^{\circ}$ C	0.02 μ V/ $^{\circ}$ C	0.02 μ V/ $^{\circ}$ C
Power Supply	± 0.8 to ± 18 V, 20 μ A	± 15 V @ .5mA	± 15 V @ 0.5mA	± 2.5 to ± 7.5 V
Input Range	Neg. Rail to V _{CC} -1.5V	+12V to -15V	+12V to -15V	+3V to -4.5V
Output Range	100 μ V to V _{CC} -1V	± 14.6 V	± 14.6 V	Rail to Rail
Open Loop Gain	700,000	1,000,000	1,000,000	10 ⁹
10Hz Noise	3 μ V p-p	1.2 μ V p-p	1.2 μ V p-p	0.3 μ V p-p

MAXIM

Fortunately, the "good" old days of precision op amps are gone. These high precision amplifiers offer the designer high performance with a wide choice of power

supplies, yet won't break power consumption or financial budgets.





MAXIM

"Increased Precision"

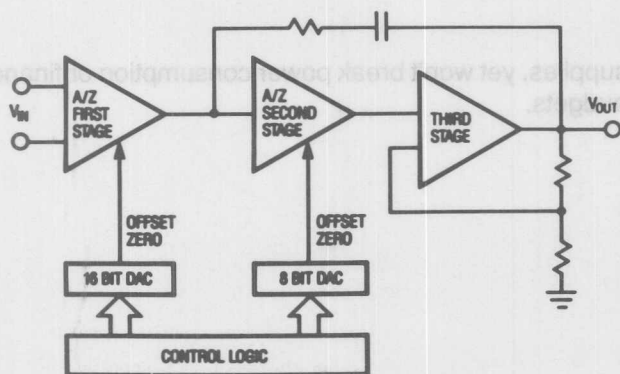
MAX425 SUPER AMP

- Digital Autozero - no decay
- Contains 16-bit and 8-bit D/A
- Sum of all DC errors less than $1\mu\text{V}$
- Near-infinite gain - 180db
- 15MHz gain-bandwidth
- 3 Autozero modes
 - 1) On command
 - 2) On power-up
 - 3) Every minute
- 8 pin standard pinout - no external components

MAXIM

The MAX425 "Super Amp" is particularly unique, since it has less than $1\mu\text{V}$ of offset at 125°C and still functions at 200°C . Input noise is also superior to the quietest monolithic chopper stabilized amplifiers, including Maxim's own MAX420. Typical MAX425 noise is below $0.1\mu\text{V}_{\text{P-P}}$ in a 1Hz bandwidth.

"MAX425 Super Amp"



MAX425 SUPER AMP

MAXIM

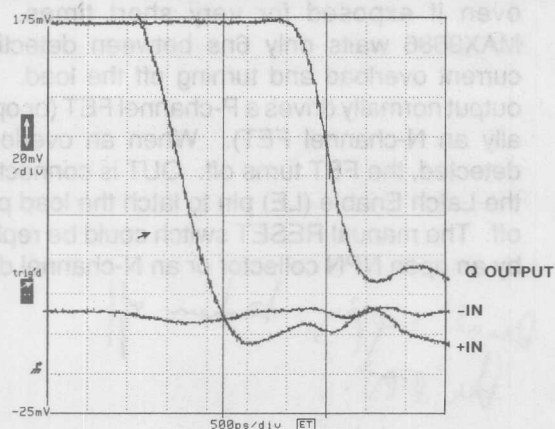
The MAX425 and MAX426 (high speed) provide input offset and noise specifications superior to chopper stabilized amplifiers but use no external capacitors. Two independent error correction schemes operate on-chip: A unique input switching design takes care of offset, while internal amplifier errors are removed with digital correction to reduce common mode error and nearly eliminate clock ripple. The MAX425 is unity gain stable and has a 350kHz gain-bandwidth product. The MAX426 is uncompensated with a gain-bandwidth product of 12MHz. Signal input and power supply connections conform to the standard op-amp pin configuration.

New Fast Comparators

PART NO.	LOGIC FAMILY	PROP. DELAY	OUTPUT
MAX9690	Single ECL	1.3ns	Complementary
MAX9685	Single ECL	1.3ns	Complementary w. Latch
MAX9687	Dual ECL	1.4ns	Complementary w. Latch
MAX9686	Single TTL	6ns	Complementary w. Latch
MAX9698	Dual TTL	6ns	Complementary w. Latch
MAX900	Quad TTL	8ns	Single-Ended w. Latch
MAX901	Dual TTL	8ns	Single-Ended w. Latch

A new family of high speed comparators offers performance combinations previously not available. At one end, the MAX9685 provides the shortest propagation delay at 1.8ns (typ) max. At the other, the MAX900 combines four 8ns latched comparators on one chip, but consumes only 70mW total.

ECL Comparator Response Time

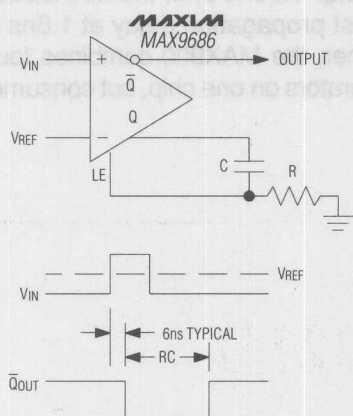


This photo demonstrates the speed possible with the MAX9685. The left-hand transition is the signal at +IN as it passes the (relatively flat) -IN threshold. The right-hand transition is the Q output ($\bar{Q}$ is also provided). Vertical lines mark the time between the inputs crossing and the 50% point of the output. This typically takes only 1.3ns.

Comparing Comparators TTL vs. ECL

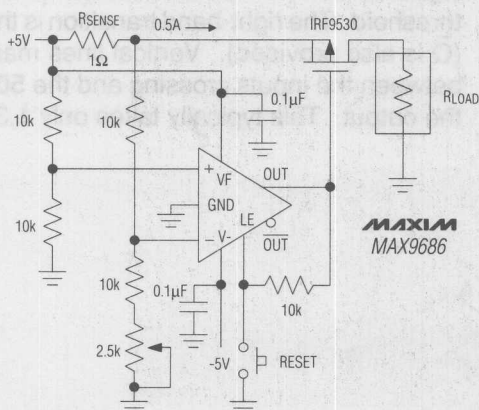
Parameters		TTL Family	ECL Family
Speed		200MHz	600MHz
Delay		6ns	1.3ns
Power Supply	Voltage	+5V, -5V	+5V -5.2V
	Current	20mA	20mA
Input Offset	Voltage	$\pm 3\text{mV}$	$\pm 5\text{mV}$
	Current	$25\mu\text{A}$	$40\mu\text{A}$
Latch Set-Up Time		2ns	0.5ns

10ns "One-Shot"



The MAX9686's complementary outputs and latch input can be utilized to produce an "impossibly short" one-shot. A significant advantage over other one-shots is that it can be triggered from small amplitude, high frequency analog voltages rather than digital inputs. This is particularly handy in input trigger circuits for high speed signal analyzers, digital oscilloscopes, and recorders.

High Speed Power Disconnect



This high speed circuit protects sensitive loads that can be destroyed by excessive current, even if exposed for very short times. The MAX9686 waits only 6ns between detecting a current overload and turning off the load. The output normally drives a P-channel FET (or optionally an N-channel FET). When an overload is detected, the FET turns off. OUT is connected to the Latch Enable (LE) pin to latch the load power off. The manual RESET switch could be replaced by an open NPN collector or an N-channel drain.

Dual supply to turn off the FET.

MAX900 Low Power, Quad, 8ns Comparator

- Separate Analog & Digital Ground *+ supply.* Improves Stability & Noise Rejection
- Analog Inputs can Exceed Logic Levels
- 0-10V Analog Supply; +5V Digital Supply
- Inputs Valid Down to Negative Supply Rail
- Low Power (70mW with +5V Supply)
- Separate Latch Inputs for Each Comparator

APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLEXERS

- Input

VIDEO PROCESSORS

- Cross

RS-232

- Isolation

CIRCUITS

RS-232

■ **Isolation**

MAXIM

RS-232 LINE DRIVERS/RECEIVERS

+5V, 4 EXT. CAPS

2DRVRS/2RCVRS

- MAX220
- MAX222 (Low Power)
- MAX232
- MAX232A (FASTER)
- MAX242
- MAX243

HIGH DRVRS/RCVR COUNT

- MAX230 (5 DRVRS/0 RCVRS)
- MAX234 (4 DRVRS/0 RCVRS)
- MAX236 (4 DRVRS/3 RCVRS)
- MAX237 (5 DRVRS/3 RCVRS)
- MAX238 (4 DRVRS/4 RCVRS)
- MAX240 (5 DRVRS/5 RCVRS)
- MAX241 (4 DRVRS/5 RCVRS)
- MAX244 (8 DRVRS/10 RCVRS)
- MAX248 (8 DRVRS/8 RCVRS)
- MAX249 (6 DRVRS/10 RCVRS)

+5V, INTERNAL CAPS

2DRVRS/2RCVRS

- MAX223
- MAX233

HIGH DRVRS/RCVR COUNT

- MAX235 (5 DRVRS/5 RCVRS)
- MAX245 (8 DRVRS/10 RCVRS)
- MAX246 (8 DRVRS/10 RCVRS)
- MAX247 (8 DRVRS/9 RCVRS)

+5V/+12V OR BATTERY POWER, 2 EXT. CAPS

2DRVRS/2RCVRS

- MAX231

HIGH DRVRS/RCVR COUNT

- MAX239 (3 DRVRS/5 RCVRS)

ISOLATION PRODUCTS

2 CHIP SET

- MAX250
- MAX251

COMPLETE MODULE

- MAX252

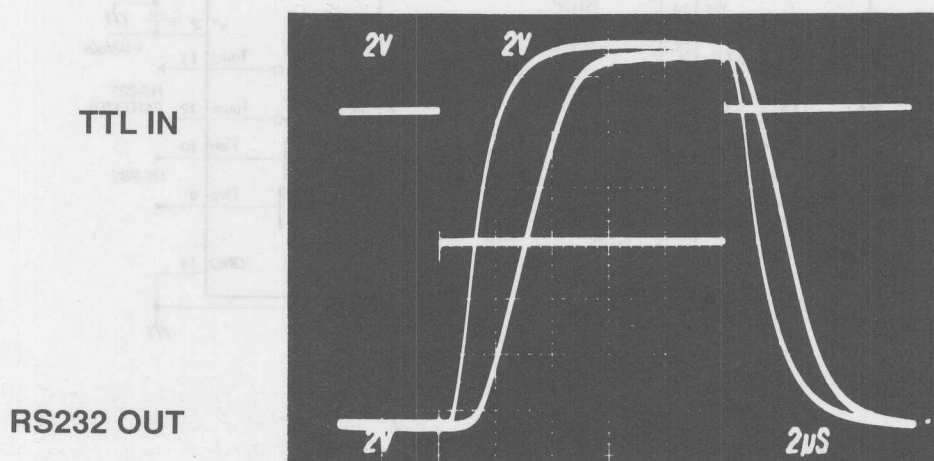
MAX232A Improved RS-232 Interface

	MAX232A	MAX232
Increased slew rate (under load)	10V/ μ s	3V/ μ s
Increased data rate	>100kBit/s	19.2KBit/s
Smaller Charge		
Pump Capacitors	0.1 μ F	1 μ F 4.7
Same Supply Current	10mA	10mA

Pin compatible with MAX232

The MAX232A, a significantly upgraded version of the popular MAX232, allows higher speed with RS-232 type data interfaces. Features include reduced transmission delay and faster slew rate and symmetrical output drive. Even under fully loaded conditions, data rates in excess of 100kBit/s can be achieved. In addition, the voltage converter circuitry in the MAX232A will work with less expensive 0.1 μ F charge pump capacitors.

MAX232 vs MAX232A Propagation Delay and Slew Rate Comparison



A comparison between the MAX232 and MAX232A transmitter outputs, loaded with 3k Ω in parallel with 2500pF, shows slew rate, propagation delay, and sym-

metry improvements. Ground in the picture is at center screen.

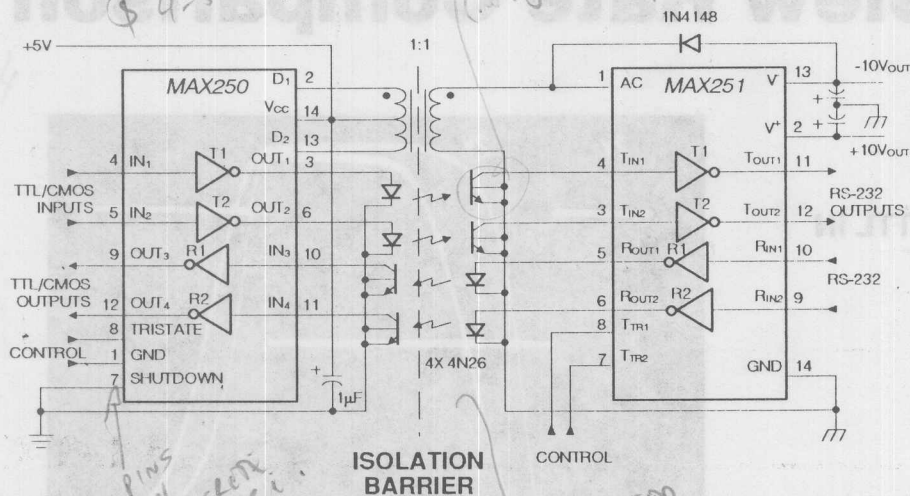
MAX252 Isolated RS-232, Single Package

- Isolated Data Interface
 - 130VRMS (continuous)
 - 1500VRMS (1 second)
- No External Components Required
- 9600 bits/sec Guaranteed (19.2kb/s typ)
- Single +5V Supply
- 50μW Low Power Shutdown
- Two Transmitters and Two Receivers
- UL Qualification Expected – September 1990

MAXIM

The MAX252 offers a complete, electrically isolated, RS-232 interface. Two line drivers and two line receivers are included in a single package along with opto-isolation circuitry. No external components are needed. UL approved devices will also be supplied.

MAX252

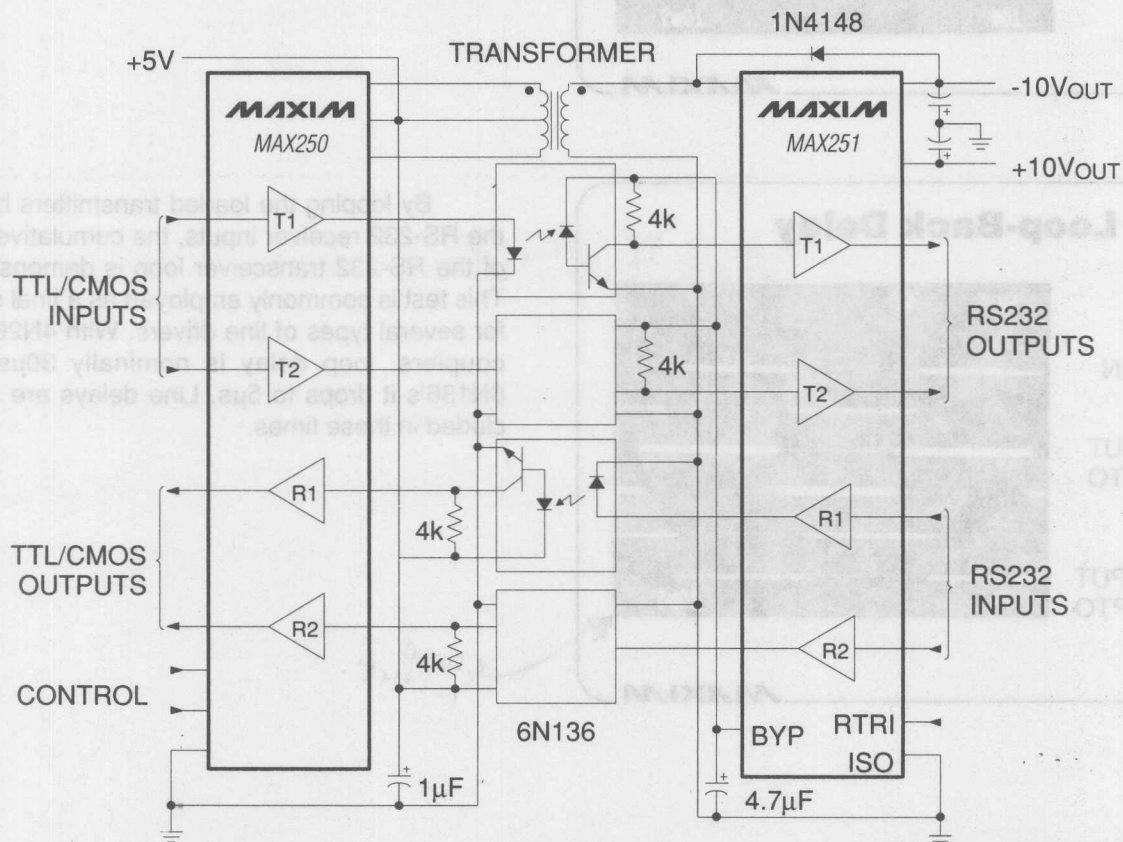


MAXIM

The MAX252 utilizes Maxim's proprietary "Lead-Frame Hybrid" technology to incorporate the MAX250,

MAX251, power supply, and isolation components in a standard 40-pin dual in-line plastic package.

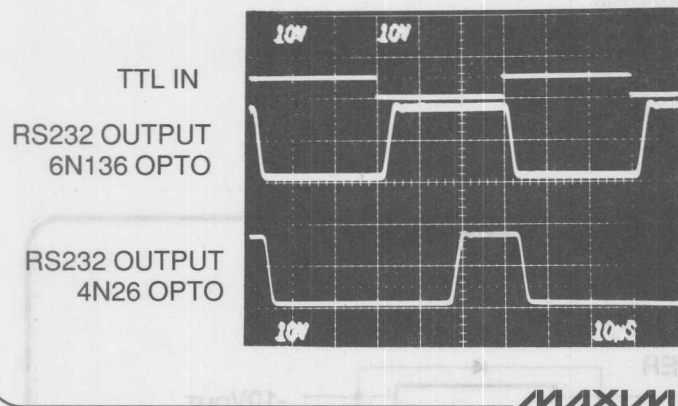
High Speed Isolated RS232 Interface 6N136 Isolators



The MAX250/251 chip set is used with four opto-couplers and a transformer to create a 1500V isolated RS232 interface. 4N26 opto-couplers can be used in the standard data sheet circuits for data rates up to 19.2

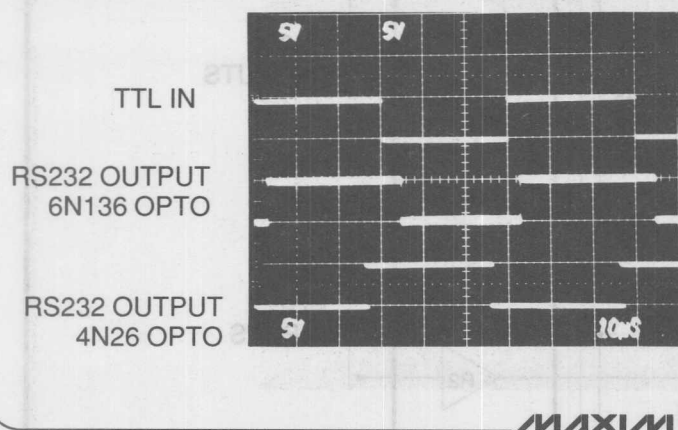
kbits/sec. This circuit shows that with higher speed 6N136 opto-isolators, the MAX250 can operate at data rates up to 90 kbits/sec.

MAX250/251 Loaded Transmitter Waveforms



Using 4N126's, the transmitted (upward rising) RS-232 signal is delayed by almost 20µs. By comparison, the transmission delay with 6N136 opto-couplers is substantially less.

Loop-Back Delay



By looping the loaded transmitters back to the RS-232 receiver inputs, the cumulative delay of the RS-232 transceiver loop is demonstrated. This test is commonly employed as a final screen for several types of line drivers. With 4N26 opto-couplers, loop delay is nominally 30µs, with 6N136's it drops to 5µs. Line delays are not included in these times.

APPLICATIONS

POWER SUPPLY DC-DC CONVERTERS

- Battery Power

A/D CONVERTERS

- Serial Apps

ACTIVE FILTERS

- Lower Noise

ANALOG MULTIPLIERS

- Input

VIDEO

- Circuit

RS-232

- Isolation

μP SUPERVISORY CIRCUITS

μP Supervisory Circuits

MAXIM

μP SUPERVISORY CIRCUITS

FIVE FUNCTION* 16 PIN

- **MAX691** (4.65V reset)
- **MAX693** (4.0V reset)
- **MAX695** (200ms reset pulse width)
- **MAX791** (monitor backup batt)

FOUR FUNCTION* 16 PIN

- **MAX696** (adj. reset threshold)
- **MAX697** (adj. reset threshold)

FOUR FUNCTION* 8 PIN

- **MAX690** (4.65 reset)
- **MAX692** (4.0V reset)
- **MAX694** (200ms reset pulse width)
- **MAX790** (improved MAX690)

RESET & WATCHDOG

- **MAX698** (reset only)
- **MAX699**
- **MAX700** (reset only, adj hyst)
- **MAX701** (reset only)
- **MAX702** (reset only)
- **MAX1232** (improved DS1232)

UNDER/OVER VOLTAGE DETECTORS

SINGLE VOLTAGE DETECTORS

- **MAX8211** (non-inverting)
- **MAX8212** (inverting)

DUAL VOLTAGE DETECTORS

- **ICL7665**

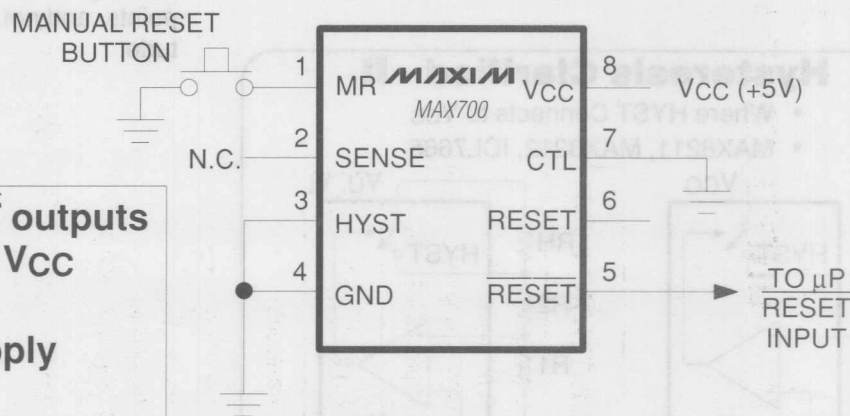
* FUNCTION TABLE:

MAX690-MAX1232 FUNCTIONS	690	691	692	693	694	695	696	697	698	699	700	701	702	790	791	MAX 1232
Fixed Power Up/ Down Reset	✓	✓	✓	✓	✓	✓			✓	✓	✓	4	✓	✓	✓	✓
Variable Power Up/ Down Reset							✓	✓			✓					✓
Battery Backup Switching	✓	✓	✓	✓	✓	✓	✓							✓	✓	
Watchdog Timer	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓	✓	✓
Power Fail Warning	✓	✓	✓	✓	✓	✓	✓	✓						✓	✓	
Write Protect		✓		✓		✓		✓							✓	

PROBLEM 690 short period battery power
whole cct at chageover → hi-imp battery ca
drop.

New Low-Cost μ P Supervisors MAX700, MAX701, MAX702

- **RESET, $\overline{\text{RESET}}$ outputs guaranteed for V_{CC} down to 1V**
- **200 μ A max supply current**



FUNCTION	MAX700	MAX701	MAX702
RESET Output	X	X	X
$\overline{\text{RESET}}$ Output	X	X	
Debounced Manual Reset	X	X	X
Fixed Reset Threshold (4.65V typ.)	X	X	X
Adj. Reset Threshold	X		
Adj. HYST	X		

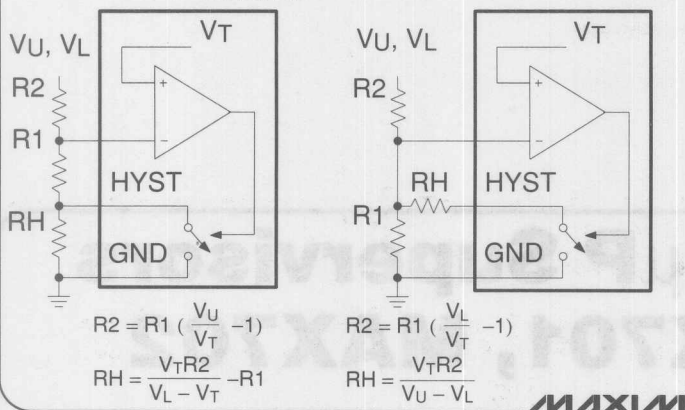
MAXIM

The MAX700, 701 and 702 monitor the power supply in microprocessor and digital systems. They supply a RESET pulse of at least 200ms on power-up, power-down, and during low voltage "brown out" conditions. Excellent circuit reliability and low cost are provided by eliminating all external components and adjustments in 5V circuits.

The MAX702, monitors its 5V supply in basic applications. Only V_{CC} , GND and RESET pins are provided. When V_{CC} falls to 4.65V, RESET goes low. The MAX701 performs the same function but includes both RESET and $\overline{\text{RESET}}$ outputs. All parts include a debounced manual reset input. The MAX700 also features adjustable hysteresis, and preset or adjustable voltage detection. This allows thresholds other than 4.65V to be selected.

Hysteresis Clarified - I

- Where HYST Connects to GND
- MAX700

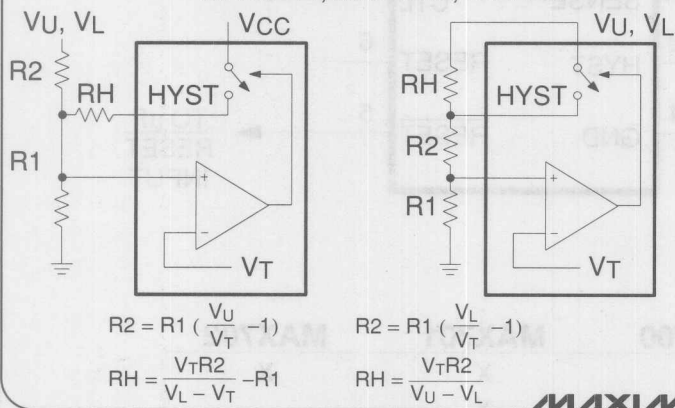


The MAX700, when connected for adjustable voltage detection, also allows adjustable hysteresis. The open-drain switch at HYST connects to ground to "pull" the R2/R1 voltage divider and shift the input threshold as a function of the output state.

Adjustable hysteresis schemes occasionally confuse designers when the circuit itself is not considered. The four block diagrams in these two slides cover hysteresis connections in Maxim products such as MAX8211/12, ICL7665, and MAX700. Either a grounded switch or a switch to VCC is used, depending on the device. Equations for each type of circuit are included. In most cases, the task of calculating appropriate resistors for the voltage trip point and hysteresis is simplified by working in terms of upper (V_U) and lower (V_L) trip points, and not directly with the hysteresis magnitude.

Hysteresis Clarified - II

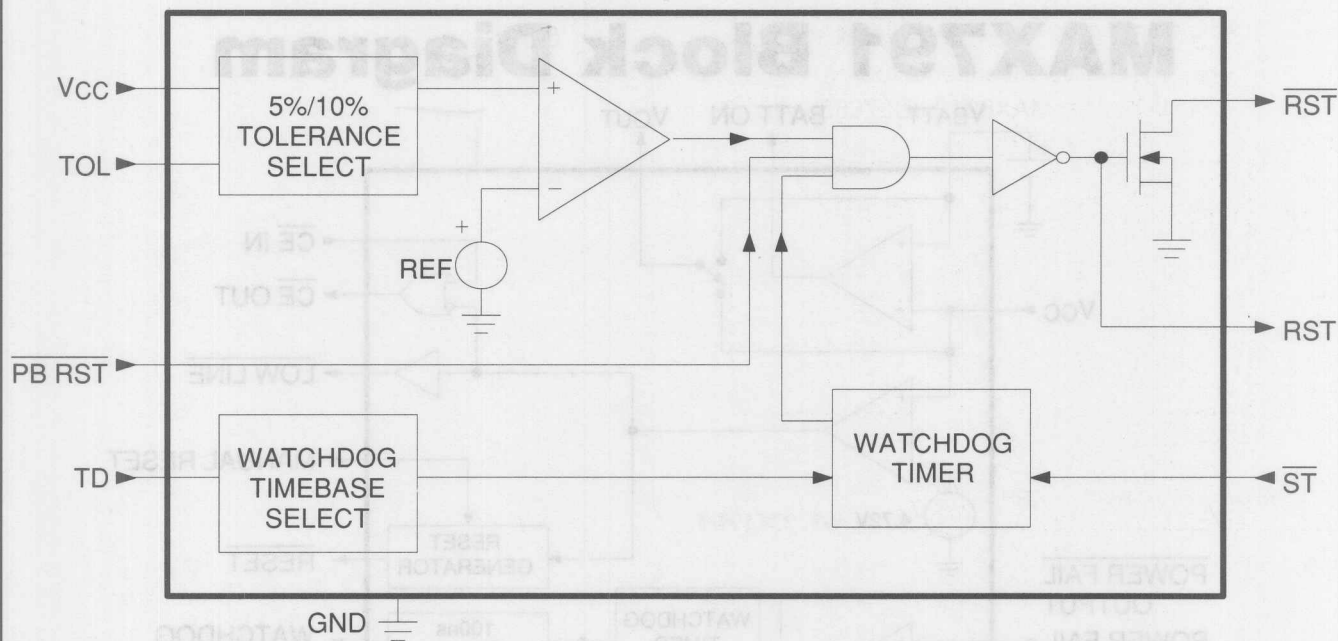
- Where HYST Connects to VCC
- MAX8211, MAX8212, ICL7665



MAX1232

Improved Upgrade for DS1232

- Pin Compatible 8-Pin DIP
- 50 μ A Supply Current vs. 500 μ A for DS1232



The MAX1232, an improved, low power replacement for the DS1232, provides a simple, compact solution for power supply and software monitoring in microprocessor systems. 5% and 10% supply tolerance can be selected digitally. The Reset outputs go active when the

power supply exceeds the selected tolerance. Reset remains active for a minimum of 250ms after the supply has recovered. A debounced manual reset input and a watchdog software monitor are also included.

MAX790/791 Spec Improvements Over MAX690 Family

	MAX790/791	MAX69X
CE Prop. Delay	10ns	50ns
Supply Current	70 μ A	2mA
V _{OUT} Current	250mA	50mA
V _{BATT} Current	25mA	1mA

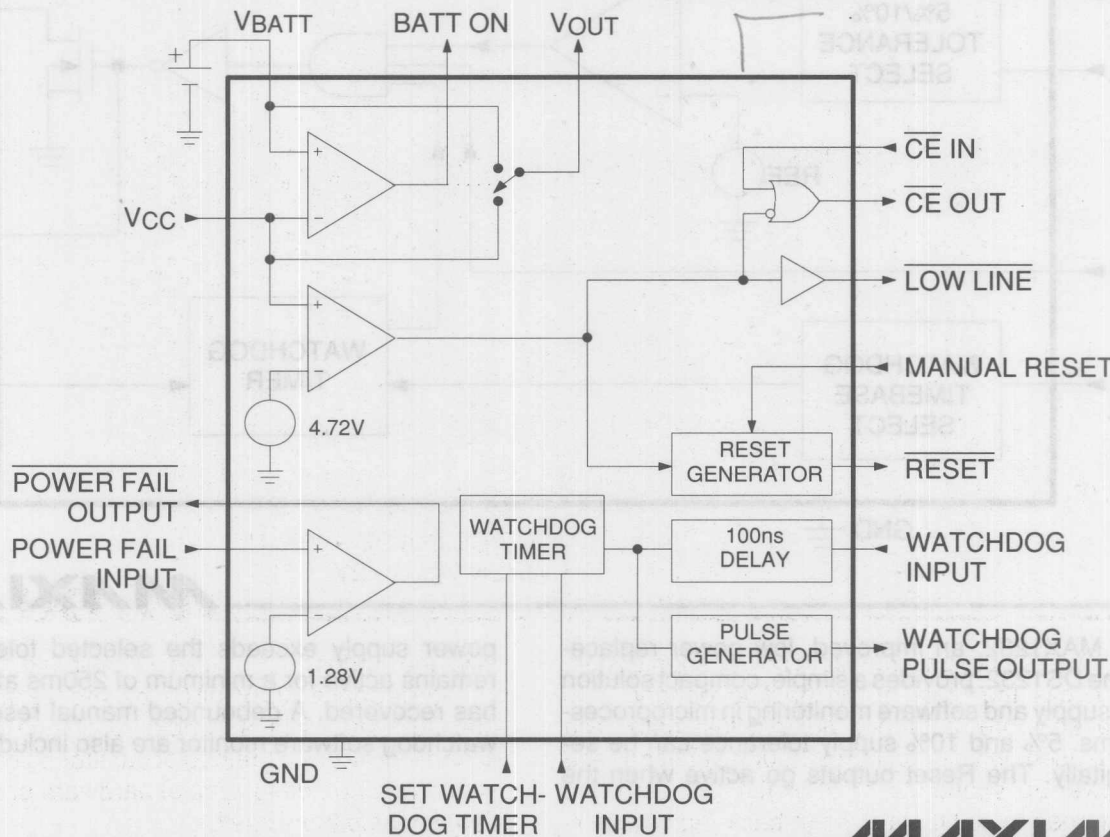
- MAX790 pin compatible with MAX690
- MAX790/91 RESET valid for V_{CC} down to +1V

MAXIM

The MAX790/791 supervisory circuits reduce the complexity and number of components required for power supply monitoring and battery control functions in microprocessor systems. The MAX790 is supplied in 8-pin packages and provides four functions:

- 1) Reset output during power-up, power-down, and brownout conditions
- 2) Battery backup switching for CMOS RAM, CMOS μ Ps, or other low-power logic.
- 3) A Reset pulse if the optional watchdog timer has not been toggled within a specified time.
- 4) A 1.28V threshold detector for power fail warning, low battery detection, or to monitor a power supply other than +5V.

MAX791 Block Diagram

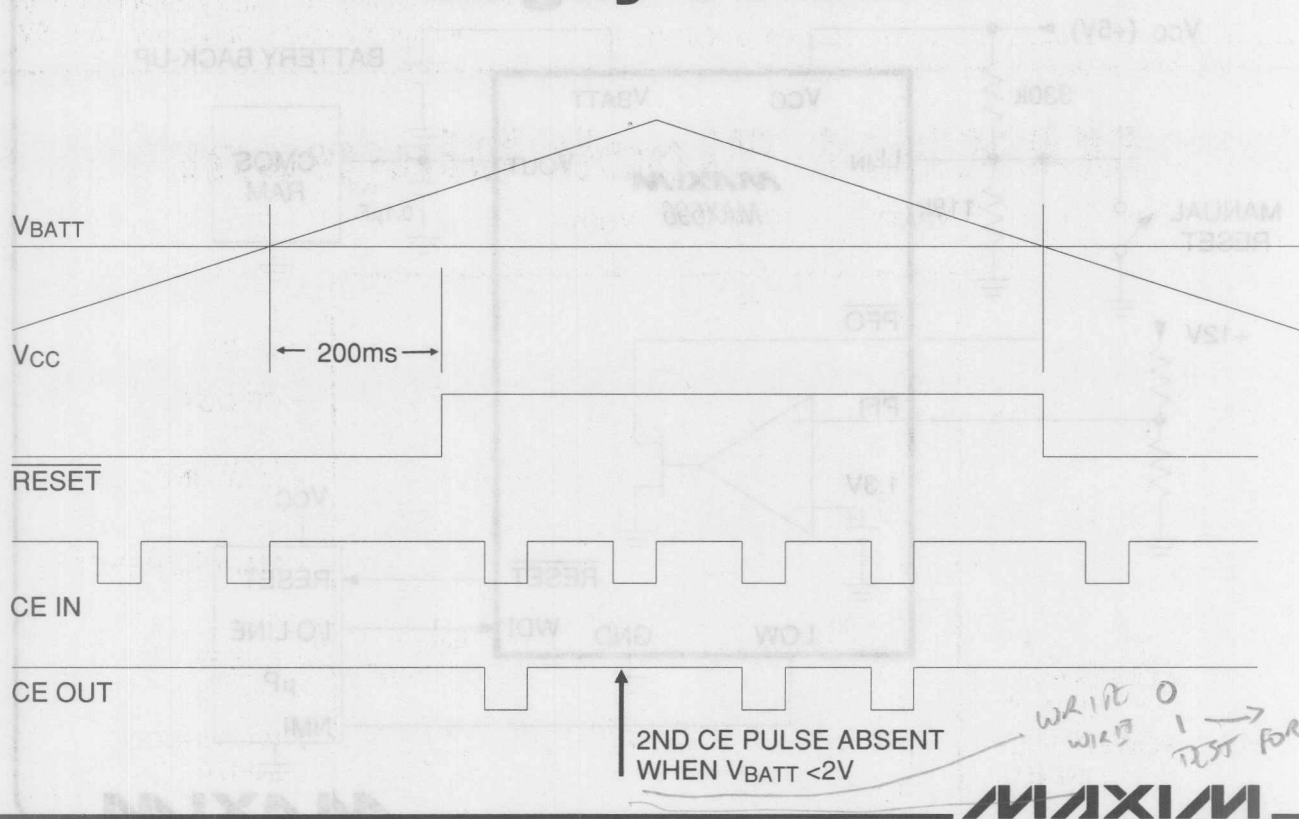


MAXIM

The MAX791 is supplied in 16-pin packages and performs all the functions of the MAX790, plus:

- 5) Manual Reset Input
- 6) Preset or adjustable watchdog time-out period
- 7) Backup battery voltage monitor
- 8) Write protection for CMOS RAM or EEPROM
- 9) Back-up battery "ON" output
- 10) Pulsed watchdog output - to distinguish watchdog resets from resets activated by other means

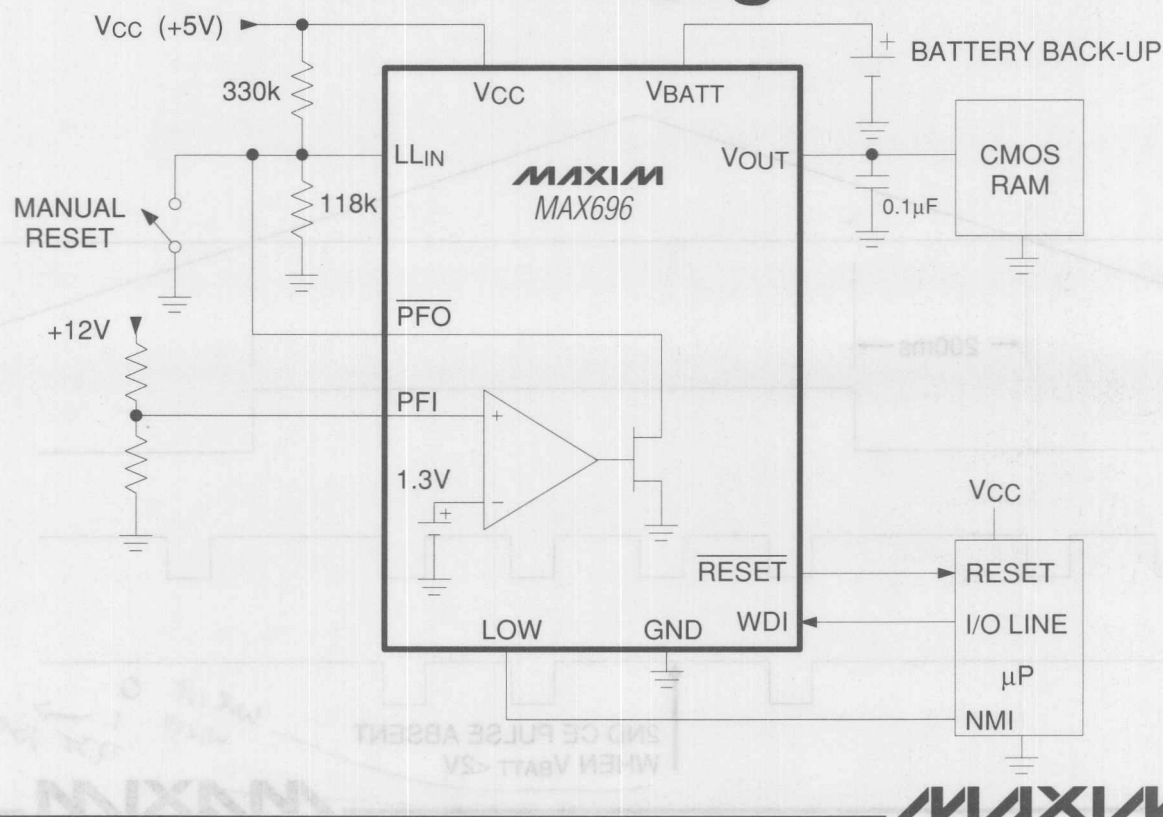
MAX791 Monitors Back-Up Battery Status



The MAX791 not only monitors power supply lines, but also checks the state of the backup battery. This provides even more insurance against lost data. The battery is sensed only during reset (200ms) either after a normal power-up sequence or after the manual reset (MR) is returned to its HI state. If the back-up battery is

low, the second CE pulse is inhibited. If the battery voltage is above +2.2V, all CE pulses are allowed through the CE gate. With a simple routine in software, this scheme provides a method of monitoring back-up battery status with no added system hardware or other connections to the battery itself.

Supervisory Circuit Monitors Two Voltages



The MAX696 supervisory circuit reduces the complexity and number of components required for power supply monitoring and battery control functions in microprocessor systems. These include uP reset and backup-battery switchover, watchdog timer, CMOS RAM write protection, and power failure warning.

In this application, the MAX696 monitors both a +5V and a +12V supply. By monitoring both supplies, the uP can perform a controlled power-down sequence when the MAX696 senses that either power supply is failing. The +12V supply is monitored through the PFI input. PFO pulls LLIN low, triggering a reset, when the +12V supply falls to +11.5V.